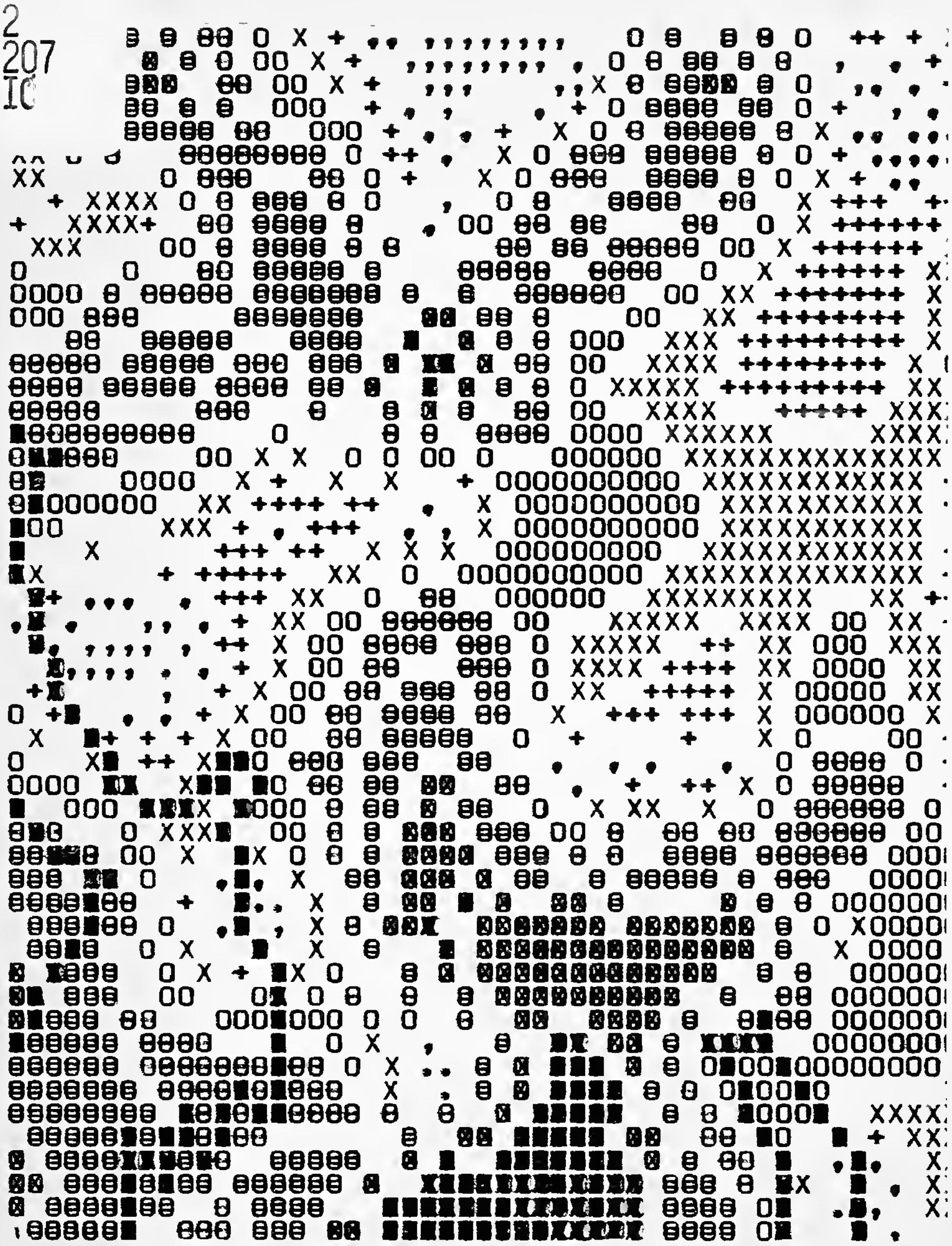
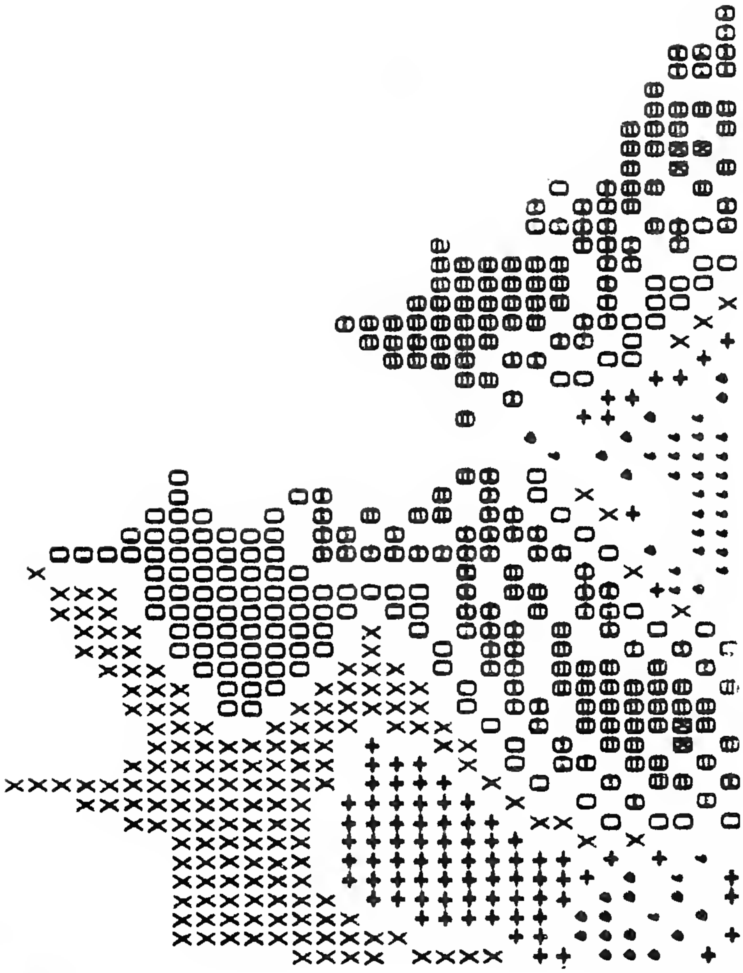


**MARYLAND AUTOMATED GEOGRAPHIC INFORMATION SYSTEM**

# technical series may 1974

## Generalized Land Use Plan

Maryland Department of State Planning



# maryland automatic geographic information system

TECHNICAL SERIES DECEMBER 1973

GENERALIZED LAND USE PLAN

PUBLICATIONS.

MARYLAND. DEPARTMENT OF STATE PLANNING

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# Preface

The publication of this manual is simultaneously a denouement and a beginning. As documented within, a vast amount of data has been collected and reformatted for use by all involved or interested in planning. This data, within a short time, will be readily available both in digital and traditional map form. The creation of the Maryland Automated Geographic Information (MAGI) System is even more important. The capabilities of this system will grow in time as it is used more frequently as a tool in planning and decision making.

The System in its broadest construction has evolved with State, U. S. Department of Housing and Urban Development, and National Aeronautics and Space Administration funding. In its earliest stages MAGI will service the Department's mandate to act as the principal planning agent of the Governor and provide planning assistance to the General Assembly. The preparation of a Generalized State Land Use Plan and other elements of the State Development Plan will serve as the focus of the planning efforts.

The potential of MAGI for interfacing remotely sensed data as available through NASA's Resource Technology Satellite program is left unreported in this document though it exists in a significant manner. The Department as a Principal Investor in the ERTS program will elaborate on this topic in the near future through the NASA Reporting System.

Additional applications of the system will be tested on a continuing basis to serve state and substate planning and decision-making needs. The Department of State Planning will make every attempt to keep interested parties advised of the growth of MAGI and its uses.

John C Antenucci

John Antenucci

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# 1. Introduction

The legislation creating the Maryland Department of State Planning (Articles 41 and 88C, Annotated Code of Maryland) assigns to the Department the responsibility of preparing and keeping up to date "a plan or plans for the development of the State, which plan or plans collectively shall be known as the State Development Plan."

In addition to numerous special studies, the Department of State Planning is currently preparing a State Development Plan. The aim of this plan is to provide a coordinated basis for guiding the future development of the State in order to assure the general welfare and prosperity of the people of Maryland. The plan is to be based on studies of social, economic, and physical conditions as well as trends in the State, and will examine these conditions and trends with the intention of establishing objectives within a goals-oriented framework. The plan, in order to emphasize equally the best use of the State's physical resources and the well being of its citizens, has two major elements: the Land Use Plan and the Human Resources Plan.

This report describes the methodology and technical factors associated with the development of the Maryland Automated Geographic Information (MAGI) system designed to assist in the Maryland state planning and land management effort.

The MAGI system was designed and implemented by Environmental Systems Research Institute (ESRI) of Redlands, California, under the joint sponsorship of the State of Maryland and the National Aeronautics and Space Administration. It was felt that the specific approach taken for the MAGI system might serve as a demonstration study for other states in the use of an automated procedure for analysis of geographic data. Therefore, the documentation details the MAGI system as well as the methodology employed in its development.

The data bank and computerized system developed for Maryland was initially utilized to generate computer maps displaying the capability and suitability of land for various uses across the geographic extent of the State. The input used to create these computer maps was a composite of numerically weighted map variables collected and stored in a geographically referenced data bank. These computer maps will be subsequently used for a variety of planning efforts relating to the development of the Generalized State Land Use Plan. Research aimed at using MAGI to assist the interpretation of both photographic and digital satellite data from the Earth Resource Technology Satellite 1 is ongoing, and substantial benefits and applications are anticipated.

The objectives of this project. however, go beyond the initial resource inventory, data base development, and analysis of land use potentials. The system and software, as detailed in this report, establish a basic structure for continued state-wide integration and analysis of geographic statistics. The development of this system will greatly enhance the initial planning capabilities for the State and will alao continue to be a flexible data framework

for ongoing planning and management of the State's natural and cultural environment. The MAGI system will not replace all forms of manual data handling. It will, however, operate as a tool for increasing analysis capabilities and decreasing costs for data retrieval.

# 2. General Discussion

The MAGI system stores geographic data in a consistent and coordinated manner, similar to an integrated base mapping system. The information stored in this system can be displayed via computer maps in a manner similar to standard map graphics. However, unlike a normal mapping system, the structure of the MAGI system provides many advantages for complex information studies involving massive amounts of data. Specifically, the system provides a quantitative framework for rapid retrieval and analysis of information in a manner easily understandable, highly accurate, and cost effective.

## 2.1 System Objectives

Within the last ten years, there have been numerous attempts to develop automated procedures for the interpretation of geographic data. There are two basic reasons for the development of these systems: 1) increased technological capability for manipulating large quantities of data; and 2) a reduced per unit cost for information provided.

Realizing the potential benefits of such a system, the Maryland Department of State Planning initiated six generalized tasks leading to a statewide planning information system. These tasks are outlined as follows:

1. The selection of significant geographic indicators which influence intelligent decision-making for land use planning and management.

2. The collection of existing base maps and creation of new base maps which describe significant geographic variation according to the selected indicators.

3. The development of automated computer files for geographic data (i.e., digital files of spatially referenced map information).

4. The design and development of computer programs and procedures for storage, analysis, retrieval, and update of the digitized data.

5. The development of computer models for the analysis of data to be used for planning decisions.

6. The development of in-house capability for operation of the system; specifically, training state agency personnel in the use of the system.

The first of these tasks necessitated selection of a form of classification for geographic variables which would provide information for the complex planning decisions to be made by the State. The selection process required

the evaluation of existing data in the State, as well as potential new data collection. In this context, selected indicators of natural and cultural processes were chosen and prioritized, based on their significance for statewide planning.

"Soil" is an example of a high priority data item. The soil classification scheme provides interpretations such as: areas that have unstable land for construction; areas that may be within a floodplain, wetland areas; areas with high potential productivity for farming, etc. The quantity and usefulness of information derived from this single variable made it a high priority data item on the list.

Priorities for data acquisition and the costs associated with data collection were evaluated against the total budget for the project. Through this evaluation, a list of appropriate data items for inclusion in this phase of the system's development were selected. The data items and the specific criteria used for their selection are discussed in detail in Section 3 of this report.

The second task involved the collection of existing maps and the creation of new data maps for the entire state. This task represented one of the basic requirements for development of the system. It required interface with various federal, state, and local agencies, as well as private groups, for the acquisition and development of consistent data maps suitable for digitizing into machine readable files. These maps included soils, geology, topographic slope, mineral resources, surface hydrology, groundwater, vegetation, sewer and water facilities, land use, transportation, public land ownership, historic sites, and natural environmental areas for 23 counties and the city of Baltimore.

The third task was the development of automated data files describing the mapped variables listed above. These data files were essentially computer readable maps stored in a format facilitating application to a variety of analytic planning efforts. The method of "digitizing" utilized a grid cell and polygon identification procedure to identify various points, lines, and areas of geography as described on the original maps for the State.

The fourth task was the design and development of computer procedures and programs for the storage, analysis, retrieval, and display of the data contained in the automated files. This required the development of a flexible system which would not only efficiently process and maintain the existing data variables, but which could also, in the future, handle new data without significant difficulty. Part of this flexibility includes the capacity for updating the files with new information related to changes in land use, transportation, etc. This task culminated in the development of an integrated software system to be used as a "tool box" for data handling and planning analysis.

The fifth task involved transforming the data bank files into meaningful information maps for land use planning decisions. An automated procedure was used to overlay data variables and weight them according to specified values related to the capability and suitability of the landscape to sustain various land uses.

The sixth task involved the training of state agency staff in the use of the planning information system. ESRI consultants assisted the state per-

sonnel in learning the software procedures and how they can be used to conduct various forms of analysis using the digital data files. This task also included setting up the software at the state facility and conducting a seminar series for users in ways of operating and applying each of the programs for specific analysis and mapping.

## 2.2 Geographic Information and Its Analysis

The MAGI system required as input various maps of those natural resources (e.g., soils, vegetation, mineral resources, etc.) and cultural geography (e.g., land use, transportation, etc.) selected as indicators for land use planning. These maps depict polygons, lines, and points of geographic distinction (see Figure 1).

The polygon maps define the borders of homogeneous features as well as the characteristics associated with those features (e.g., a soils map describes the boundary characteristics of soil types).

Line maps define linear elements of geography such as roads, hydrologic networks, railroad lines, etc.

Point maps locate the geographic position of events or phenomena located at specific points (e.g., historical landmarks, wells, or traffic intersections). The diagram on the following page is a schematic representation of these basic geographic information types.

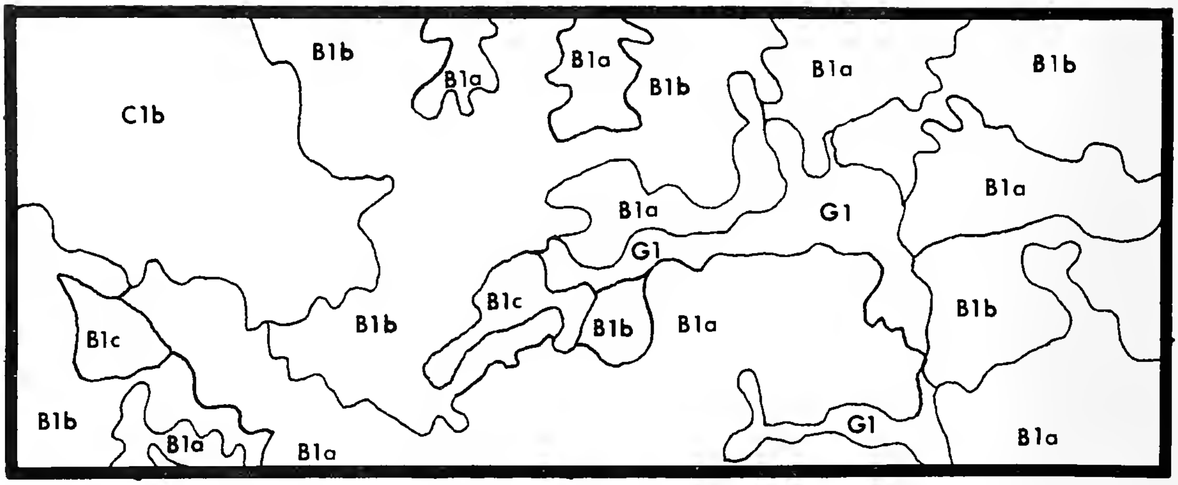
The MAGI system entailed converting maps from all three of these categories into digital data readable by the computer. "Geocoding" is a term typically used when referring to the process of specifying a geographic location in machine readable form. This process requires identifying all map data according to a common geographic referencing system. The Maryland Coordinate Grid System (M.C.G.S.) projection was selected as the coordinate system for the data base. Each polygon, line, or point on the original base maps was referenced to this common grid reference system.

The procedure for referencing the variables on these maps to the M.C.G.S. involved assigning the geographic data to a grid cell lattice covering the entire State. Quantitative and qualitative data were encoded by grid cell, using both an automated and a manual technique. These procedures are described in detail in Section 3 of this report.

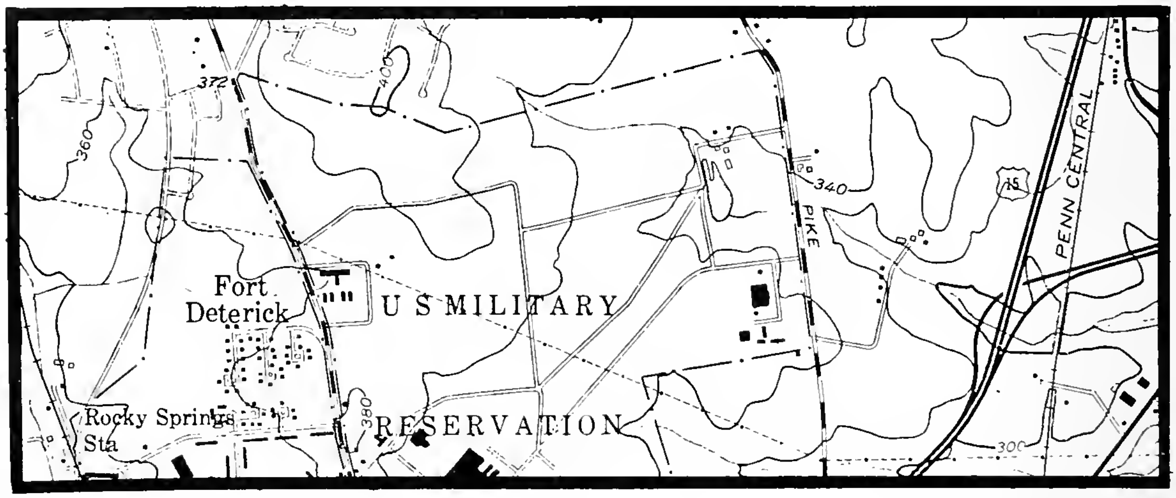
The grid cell size used for encoding or digitizing was 2000 feet by 2000 feet, or approximately 91 acres. This size corresponded to a five cell divisional breakdown of the 10,000 foot state plane lines inscribed on the base map series used for digitizing. This scale allowed a manageable level of detail, responding to the generalized planning objectives of the State.

The geographic location of each grid cell and its environmental and land use characteristics were the two basic data requirements for the MAGI system.

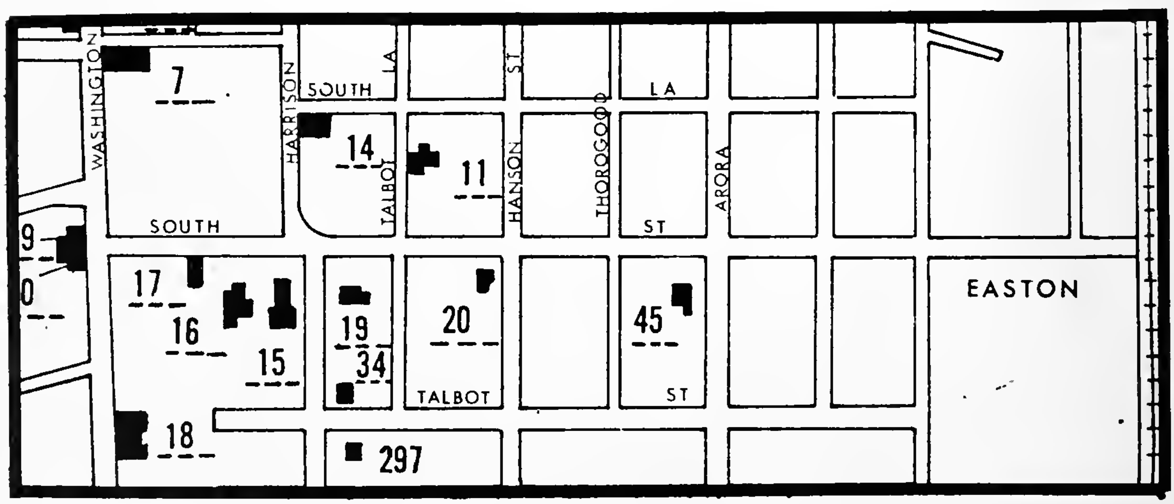
From this base information, planners can request simple data listings and display maps for such variables as soils, geology, land use, etc. Data can be displayed on these maps using shades of grey to quantitatively depict various interpretations (i.e. geology for Western Maryland - see Figure 2).




POLYGON MAP: Natural Soil Groups



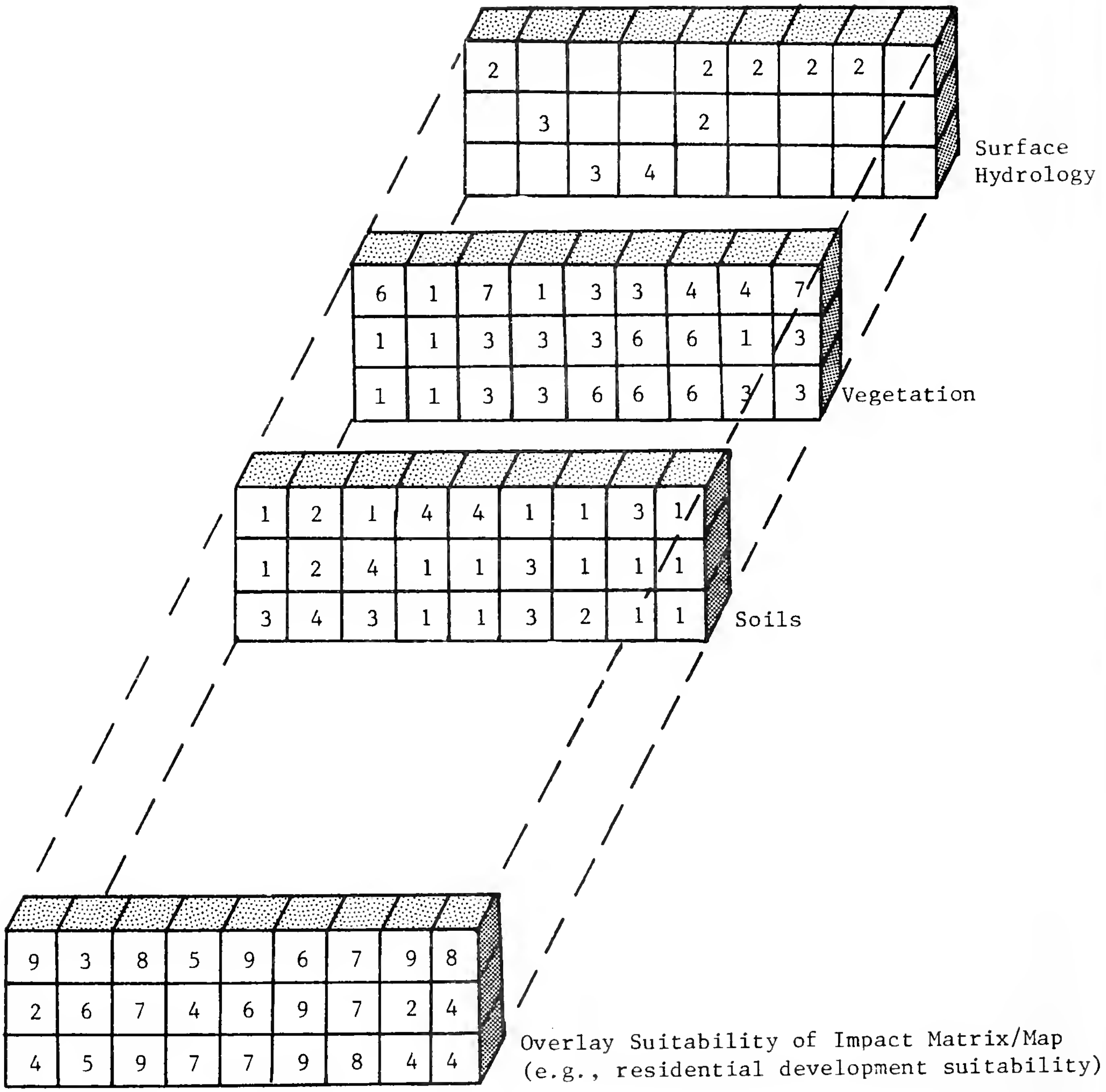

LINE (LINEAR FEATURES) MAP: Transportation System




POINT MAP: Historic Sites

FIGURE 1

FIGURE 2 GEOLOGY – WESTERN MARYLAND




NUMERIC OVERLAY MODELING PROCESS

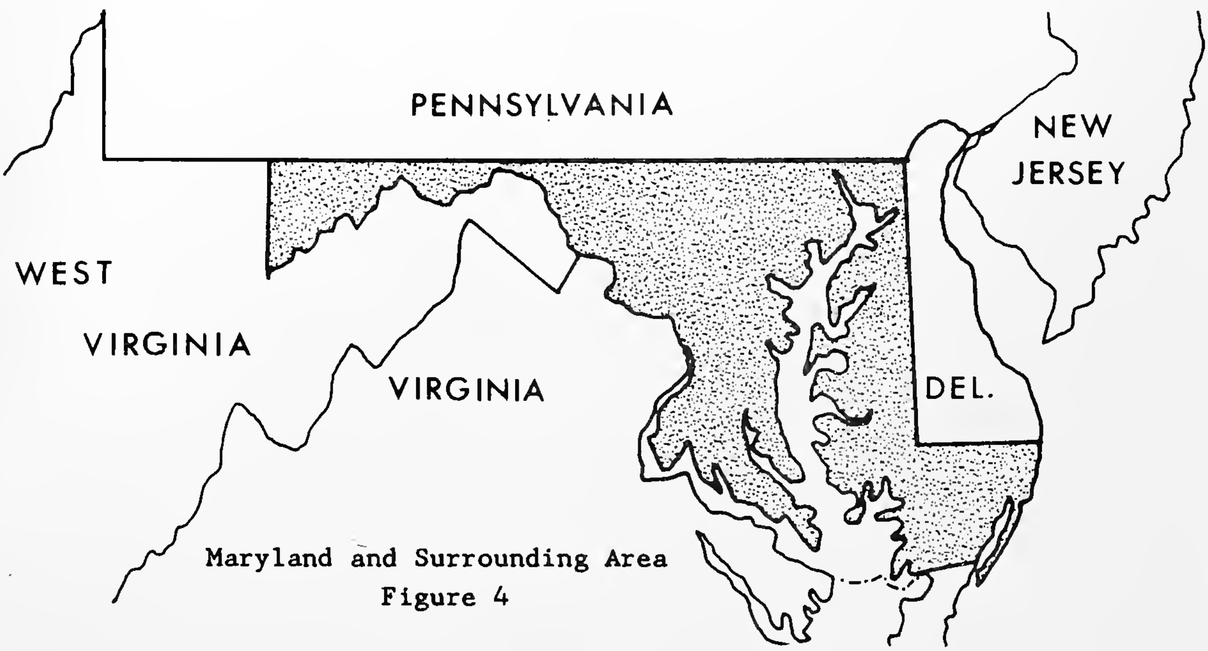
FIGURE 3

For many applications, however, more sophisticated forms of analysis are required. For example, suitability maps for housing development might require the combination or overlay of a soils map, a vegetation map, a slope map, an existing land use map, and other maps describing spatial variation. For this reason, the MAGI system was developed as an overlay system. The overlay process is conceptually similar to the manual overlay of plastic maps describing variations in geography (e.g., soils, geology, vegetation, etc.) at a constant location. The automated computer files contained in the system describe each variable according to a matrix of numerical codes. These digital matrices can be overlaid to create a numerical composite, subsequently produced in map form by the computer (see Figure 3). Normally, this is accomplished by assigning values to the variables according to some interpretation. For example, the combination of information concerning soil type, topographic slope, and vegetation type can provide a generalized picture of the erosion properties of a given area. This determination requires the development of quantitative indices of soil, vegetation, and slope as they relate to each other and as sub-classes relate within major classes. In this way, qualitative variables are interpreted and combined quantitatively to express some conceptual understanding of landscape processes, capabilities, and suitabilities.

The utilization of various computer programs and procedures enables the acquisition of data for the entire state or any given geographical subarea within the state (e.g., county, watershed, etc.). The use of this quantitative interpretation and weighting technique provides planners with a modeling methodology not previously possible with the use of manual techniques.

## 2.3 Description of Area of Application

The area covered by the geographic data files includes the entire State of Maryland (9,874 square miles of land, and 2,429 square miles of water). The state is bordered on the south by the Chesapeake Bay, Virginia, and Washington, D. C.; on the west and southwest by West Virginia; on the north by Pennsylvania; and on the east by Delaware and the Atlantic Ocean. (See Figure 4).




Maryland and Surrounding Area
Figure 4

The data within the State are varied in complexity, ranging from Appalachian Mountain regions in the western areas to flat valley plains in the eastern basin areas. The complexity of the natural resource data corresponds largely to the variability of the natural landscape regions. As a general rule, the western portions of the state were more complicated with smaller polygons of soils, vegetation, etc. than the eastern portion.

Much of the State remains in agriculture or undeveloped open space with relatively low density development. However, in the Baltimore-Washington, D. C. corridor there are major urban developments which reach high densities of population and industrial activity. This density is reflected in the distribution of various land uses.

This mixture in density of human activities, together with variation in the complexity of natural resources, proved to be a good demonstration of the system in terms of both digitizing activities and computer program operation.

## 2.4 Data Bank Variables

Two of the most critical requirements of an information system are its viability and longevity. Geographically based information is most deceiving in this respect. At first examination one would anticipate that geographically based data should be limited in scope and stable in content; on the contrary:

a. urban development is highly dynamic;

b. natural landscape systems, although not as dynamic as urban systems, are likewise not stable and are subject to change;

c. new planning methods developed to cope with regional problems may require new forms of data.

The MAGI system project invested a large percentage of its digitizing efforts in natural resource information variables which are thought to have a relatively long life span as well as a host of immediate applications. The variables selected to describe cultural geography are substantially less stable, but also have a number of immediate uses. Because of the possible changing nature of the cultural data (e.g., land use), the system includes maintenance utilities which allow quick and easy modifications to the master geographic files. A central feature of the system is a set of effective procedures and programs for extension and renewal of the data base.

Section 3 of this report will elaborate on the collection, display and encoding of different variables.

# 3. System Description

Section 2, entitled General Discussion, described the overall objectives and general framework of the information system developed by the Department of State Planning. The following section describes, more specifically, the procedures that were necessary to make the system operational. These procedures include data collection, digital conversion of maps, editing, computer analysis, and computer mapping.

Figure 5 illustrates the technical procedures employed in the development of the MAGI system. The diagram displays the interrelation of these procedures, comprising the five basic components of the system development:

a. (3.1) collection and preparation of original map data
b. (3.2) digital encoding of geographic data (digitizing)
c. (3.3) editing and file creation
d. (3.4) final data mapping of state-wide files
e. (3.5) generation of interpretive models

## 3.1 Collection and Preparation of Original Map Data

This section outlines the tasks that were necessary in collecting and preparing the data for digitizing. Included are descriptions of the data, the methods of their collection, and the method used for referencing of the data.

### 3.1.1 Selecting and Collecting Information

One of the fundamental tasks in creating a geographic information system is the construction of a consistent procedure for collecting and mapping spatial data. This becomes increasingly apparent when one realizes that data must typically be mapped as points, lines, and polygons prior to various forms of digitizing efforts.

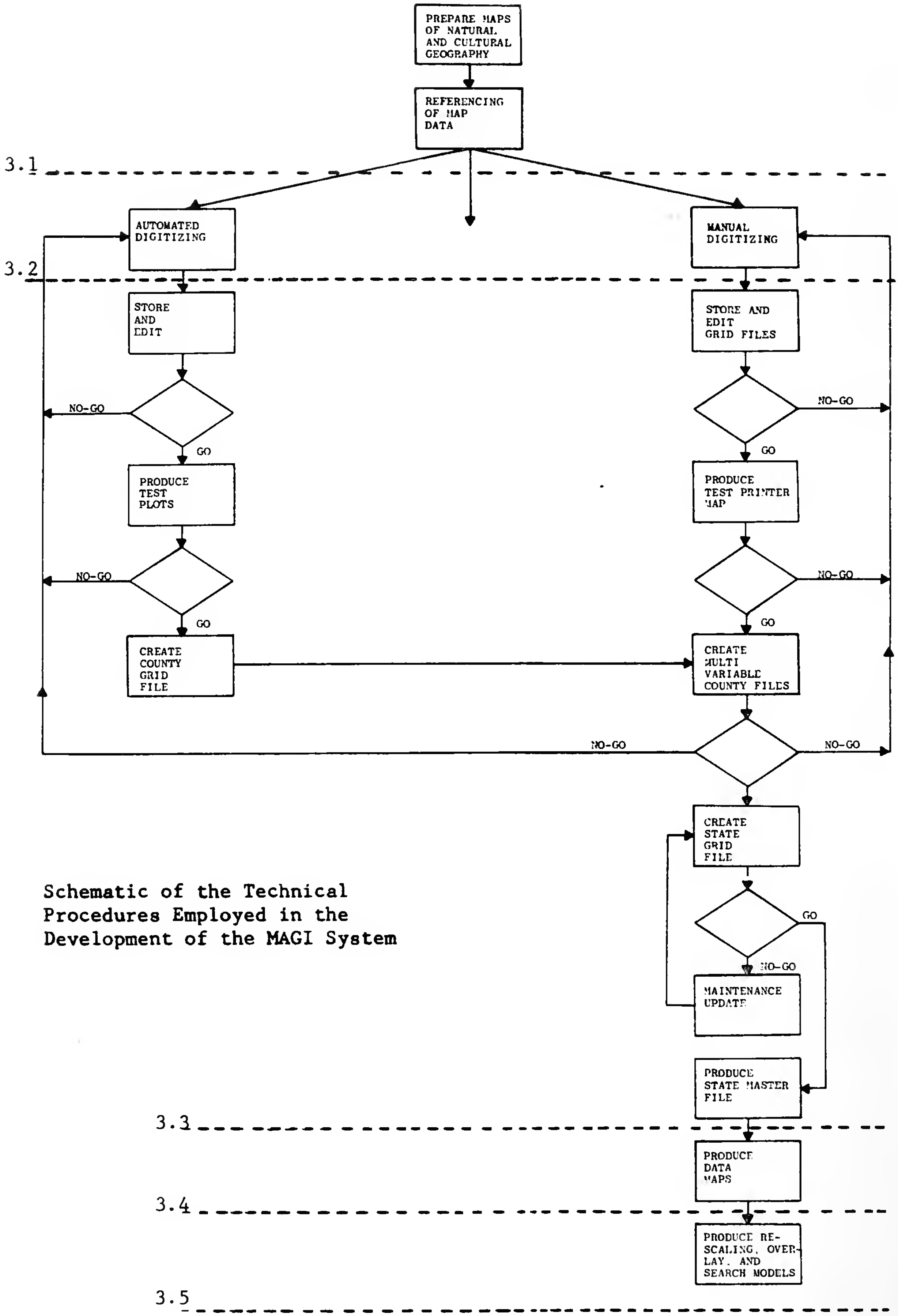
The limitations on time and funds made a major effort to create a new uniform geographic mapping system for the State impossible. Therefore, initial efforts were directed toward the following activities:

a. identifying all available sources of appropriate data and determining the resources necessary for converting them to a suitable format for digital recording;

b. determining the data's usefulness for state planning;

c. reformatting and referencing these materials to a common base for digitizing procedures.

The remainder of this section describes these activities.



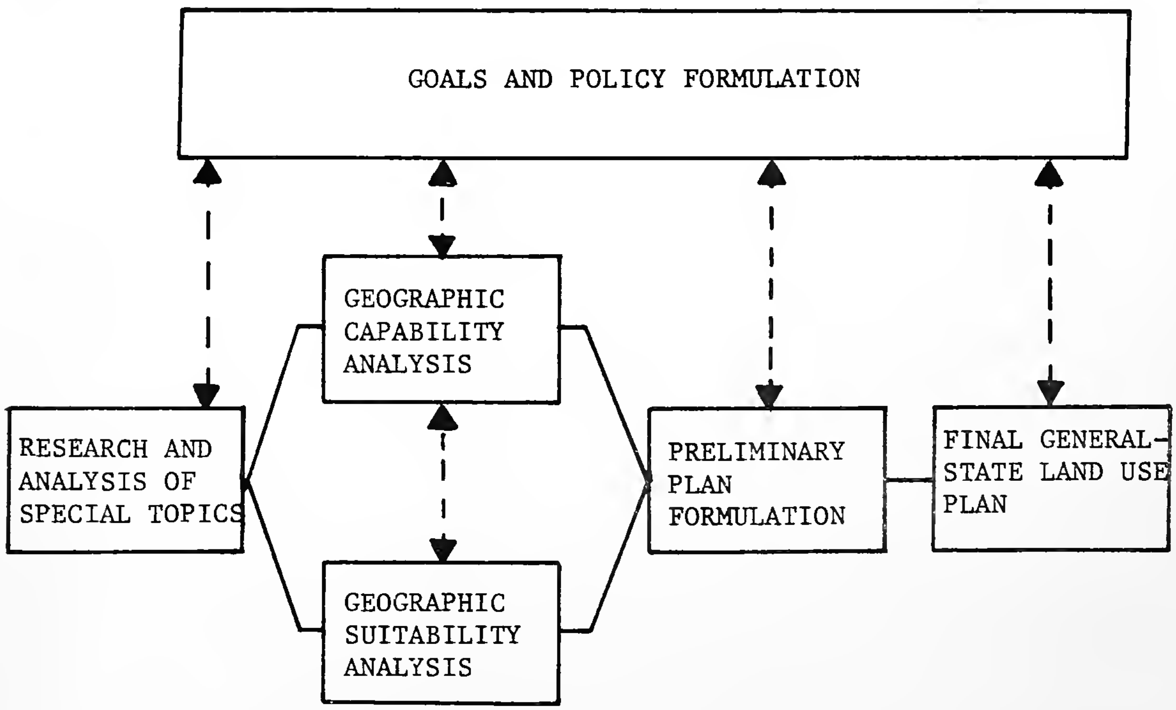

Schematic of the Technical Procedures Employed in the Development of the MAGI System

**FIGURE 5**

At the time of this project's initiation, the State of Maryland had already maintained a substantial amount of high quality data for state level comprehensive planning. This data was checked for its validity, level of applicability, timeliness, comprehensiveness, and flexibility for future uses and updating. Each data source agency was asked to identify the idiosyncrasies associated with their data and to present an analysis of the data's limitations and usefulness. Prior to reformatting the data for the information system, a review was conducted by interviewing key personnel in each of the potential data source agencies. Most of these procedures were undertaken simultaneously for a large number of variables.

Data was collected from many sources. Each of these sources maintained data of varying quality and age, with incompatible scales and drafted on different base maps. Because of budget constraints, this data was frequently not re-mapped to a single uniform data base map series. Instead, each map series was referenced to the Maryland Coordinate Grid System (M.C.G.S.) and subsequently merged during the digitizing and data processing procedure. This approach created several problems resulting in additional work during the digitizing and editing tasks. The result, however, was a major saving in budget and time resources.

The criteria for selecting data items was based on their effectiveness relative to a six step planning process as defined by the Department of State Planning. This process is outlined in Figure 6.




Steps in the Planning Process
Figure 6

Collection of data for incorporation into the data base represented one of the fundamental activities in the preparation of the Generalized State Land Use Plan.

The preceding flow diagram conveys the inherent value of the data processing system, namely that the capability or suitability analysis can reflect policy considerations and articulate these geographically using the automated data bank and computer mapping system.

A total of 15 land use variables were selected and gathered for the entire State. They were collected according to their applicability in three categories: capability analysis, suitability analysis and special studies analysis. The determination of "the ability of a resource to support various activities, and various levels of activities, because of its inherent physical characteristics" is the State's definition of capability analysis. With this definition as a guide, geographic data describing natural resources was gathered. This data was classified at a scale appropriate for determining the level of land use activity capable of being supported. This data was utilized in various models to indicate the capability of the landscape to support various land uses. Detailed discussion of the development of the capability models is provided in section 4 of this report.

Eight separate variables were collected to indicate landscape capability. The variables included soils, geology, aquifers and aquifer recharge areas, mineral resources, topography, natural features, vegetation, and surface hydrology.

In addition to these eight "capability" variables, five variables were collected for the purpose of conducting suitability analyses.

"Suitability" is defined by the State as "an entity (usually man-made, induced, or influenced) that allows one to indicate preference that a resource support various levels of activities given the equal capability of two areas." It is through the suitability parameters that the present land use, existence of public facilities, and various planned activities are accounted for. Suitability variables collected for this study included publically-owned property, sewer and water facilities, transportation systems, historic sites and existing land uses.

The five suitability analysis variables were also collected, mapped, and digitized for use in modeling the suitability of geographic areas for various land uses. Several additional non-suitability/capability data items were collected for special applications and/or analysis, including watersheds and electoral districts.

Each of the variables and their sub-components is described briefly below. A description of the eight variables used in capability analysis is presented in section 3.1.1.1 of this report. This is followed by a description of the five variables used for suitability analysis (section 3.1.1.2). The data variables used in special studies performed by the State are described in section 3.1.1.3.

#### 3.1.1.1 Capability Analysis of Data Items

a. Soils

A soil survey for the entire State existed at the outset of this effort. However, many of the county soil surveys were not yet published by the USDA-SCS. Therefore, the data available to the Department of State Planning varied in form, but was highly detailed. The Department reformatted over 300 soil classifications into 30 natural soil groups, a planning designation permitting discrete extractions of information. The grouping system was designed to respond to five basic planning considerations:

1. soil fertility
2. soil stability
3. soil permeability (runoff potential and septic capability)
4. soil erodibility
5. alluvial floodplain identification.

The soil grouping polygons were prepared for digitizing on county maps. In many instances these maps contained the more detailed soil type polygons from the original survey data as background shading. The publication scale of these maps was 1:63,360 or one inch equals one mile. The original worksheets, however, were 1:20,000 or three inches equal one mile. Both the original and the informatted maps are retained by the Department of State Planning for inspection. Technical assistance was provided by the Soil Conservation Service in College Park, Maryland.

The natural soil groups were generally arranged in order of increasing limitations or problems for most uses. Drainage class describing the wetness characteristics of the various soils was one of the prime limitations considered, thus placing the better drained soils in the first group. Soil groups were divided according to drainage class, productivity, depth to bedrock and watertable, permeability, susceptibility to flooding, stoniness, and rockiness. Sub-groups were divided according to slope/steepness when this factor represented an important feature affecting use.

Only the soil series names and land types are shown in the system. However, soil mapping units are placed in the system by slope phase if sub-groups are listed for the soil series and group.

It must be realized that groupings such as these force generalizations on specific soils. Any interpretation for a group cannot be as accurate as an interpretation for a specific soil within the group. However, the groupings are accurate enough for preparing generalized soil maps. They can also be used for preparing generalized interpretive soil maps.

It is clear that the natural soil group maps prepared for use at a county or state-wide planning scale cannot be substituted for the detailed soil survey delineations and interpretive techniques which are applicable to specific tracts of land.

The mapping of natural soils groups was a substantial work effort and was an exception to the basic rule of using existing data requiring a modicum of reformatting. In light of the long-term utility of the natural soil groupings, and the potential for their additional applications, this effort seemed to be the best, though most costly, alternative. D.S.P. Publication 199 elaborates on both the methodology and applications of the Natural Soil Grouping System.

b. Geology

The engineering geology data was primarily developed by using the Engineering Geology Tables of the Maryland Engineering Soil Study (June, 1965). Basic geological data for the State had been recast in terms of engineering applications by the Civil Engineering Department of the University of Maryland, using Maryland Highway maps (1:63,360 scale) as a base. The interpretive capabilities of this data include hardness, excavation requirements, extent of rock weathering, durability of fresh rock, and overburden thickness. The county maps which accompanied that study were modified for use as the base maps for this effort. Additional maps and reports from the U. S. Geological Survey were used to assist in this modification. The Maryland Geological Survey was consulted concerning the usefulness of this data for the geologic input to the Maryland Generalized Land Use Plan. This group assisted the Department of State Planning staff in extending the applicability of the basic geological information to the aquifer and mineral resources variables.

c. Aquifers and Recharge Areas

The primary source for major aquifers in Maryland was Groundwater Aquifers and Mineral Commodities in Maryland, published by its Department of State Planning in 1969 with the assistance of the Maryland Geological Survey and the U. S. Geological Survey.

The Coastal Plain aquifer information includes recharge areas directly correlated to specific geologic formations (see Geology) and depth of occurrence of water yielding source. This data can be cross-referenced to tabular data interpreting water quality and expected yields. Because of the sensitivity of these source materials, the aquifer and mineral data were placed on the engineering geology maps for digitizing.

The aquifers of the Piedmont and Appalachian Regions are treated differently from those of the Coastal Plain because of their geological complexity. They are described in terms of three hydrologic units which relate to productive capacities rather than depth of occurrence. The geologic formations that constitute Hydrologic Unit 1 in the Piedmont and Appalchian Regions have approximately 20 percent chance of yielding 50 gallons per minute (gpm) or more; this probability is reduced to 6 percent and 2 percent in Units II and III respectively. The hydrologic units provide both statistical inferences and a generalized representation of the water yielding characteristics of the geologic structures.

d. Mineral Resources

The Maryland Geological Survey and the U. S. Geological Survey provided the data for mineral resources within the State. Since these sources had a high degree of credibility, little additional regional study was undertaken. The geologic formation boundaries were used to help locate productive mineral commodities or deposits with development potential. However, the geologic boundaries themselves were not mapped as they were for geology and aquifers. Instead of formation boundaries, fifteen different mapping units related to mineral extraction activities were developed for use across the State, including:

| | |
|---|---|
| deep coal mine | greensand area |
| strip coal mine | diatomite area |
| sand and/or gravel pit | gas field |
| stone quarry | peat pit |
| clay and shale pit | copper deposits |
| | gold deposits |

Deep mines and strip mines were differentiated into active and inactive groups. Gas fields were divided into those under development, those in operation, and those utilized for storage. All other mineral areas identified were considered to be at some level of production depending upon the geological, economic, and social conditions within the area. These original maps were then converted for digitizing purposes by assigning number combinations to all of the symbols. Data maintained equal significance, regardless of the county of occurrence.

A cross-referencing system to the engineering geology data added significance to the parent geologic material.

e. Slope

For the purpose of indicating slope as an indicator of topography, state-wide slope maps were compiled indicating areas where the slope varies between 0-3%, 3-10%, 10-20%, and greater than 20%.

The slope maps can also be interfaced with the natural soil groups, since the soil data is identified by slope phase - generally 0-3%, 3-8%, 8-15%, 15-30%, 30-45%, and 45-60%.

The slope maps utilized by the Department of State Planning were originally produced as a part of the Maryland Engineering Soil Study noted previously. The slope maps series was improved by State Planning staff and consultants under contract to the Department. The original maps had a threefold classification system. A fourth slope group was added to this, essentially splitting the third classification (greater than 10%) into two parts. The new third partition became slopes of between 10% and 20% and the fourth, slopes greater than 20%.

f. Natural Features

Data on unique or endangered natural features and scenic areas was compiled by the Department of State Planning in an effort to update

and expand the 1968 "Catalog of Natural Areas in Maryland." Data was accrued through an exhaustive search of the literature on natural areas of Maryland, personal contact with Maryland experts in the natural sciences, and a public survey questionnaire.

The natural features maps included a wide range of unique natural areas and landmarks as well as areas enveloping particularly fragile ecologic systems and wild lands (e.g., bald eagle, osprey, and heron nesting areas). A state sponsored program creating a Maryland and national "big tree" inventory provided additional important data.

Each data item mapped was assigned a unique numerical identifier which can be cross-referenced to a computerized library retrieval system. This bibliographic retrieval system provides reference to various documents which describe, in detail, each of these natural features.

g. Vegetation

An extended search for recent vegetation surveys in the State proved futile. There was, however, one significant map series that provided the basis for a new map updating effort. This was a series of topographic quadrangle maps outling forest types produced in 1949-1959 by what is now known as the State Department of Natural Resources. This was combined with the 1970 Land Use Inventory which presented a recent delineation of the forest areas with respect to type.

These data sources, together with 1972 high altitude aircraft photography, were used to compile the state vegetation maps.

The 1970 Land Use Inventory was used to update the delineation of the forest types and boundaries presented on the 1949 Forest Inventory (see list below). A series of composite maps were prepared at a 1:63,360 scale (1 inch = 1 mile). This base map series was used to digitize the forest data for the computer system as well as to present the material in a graphic form. Further updating of these maps will occur as a product of the 1973 Land Use Inventory.

FOREST COVER TYPE

| | |
|---|---|
| Aspen - Pin Cherry | White Oak |
| Northern Hardwoods - White Pine | Red Oak |
| White Pine - Hardwoods | Cove Hardwood |
| Oak - White Pine | River Birch - Sycamore |
| White Pine | Bottomland Hardwoods |
| Hemlock | Loblolly Pine |
| Northern Hardwoods | Loblolly Pine - Hardwoods |
| Scrub Oak | Hardwoods - Loblolly Pine |
| Chestnut Oak | Red Gum - Yellow Poplar |
| Oak - Hard Pine | Southern White Cedar |
| Hard Pine: Pitch, Shortleaf and | Southern Cypress |
| Virginia Pine | Hard Pine - Oak |

h. Surface Water Quality

The base maps for surface water quality considerations were compiled from the Maryland Geological Survey, County Topographic series. This map series is at a scale of 1:62,500.

Water quality characteristics were compiled for all second and third order stream systems within the State. The majority of data was developed from The Continuing Planning Process for Water Quality Management, issued by the Water Resources Administration, Maryland Department of Natural Resources, completed in February, 1973.

Additional information on designated oyster and clam beds, indicating location and distribution of shellfish harvesting regions, was added to the base maps. This information had been compiled by the Coast and Geodetic Survey for the Maryland Department of Natural Resources, Tidwater and Fisheries Administration. Location and extent of oyster and clam beds were identified by field surveys located photogrammetrically by the Coast and Geodetic Survey. These data collection efforts were initially mapped at a scale of 1:20,000 and subsequently transferred to the 1:62,500 series for digital encoding.

Many portions of State waters do not presently meet the standards of their respective water classes and are not capable of doing so, given present day technology. In order to identify these substandard waters, the following classes were developed as separate mapping units for digital encoding:

1. Class I waters (general use and recreation)
2. Class I waters not meeting standards
3. Class II waters (shell fish harvesting streams)
4. Class II waters not meeting standards
5. Class III waters (natural trout streams)
6. Class III waters not meeting standards
7. Class IV waters (recreational trout streams)
8. Class IV waters not meeting standards
9. Oyster beds open to fishing
10. Oyster beds closed to fishing
11. Clam beds open to fishing
12. Clam beds closed to fishing

### 3.1.1.2 Suitability Analysis of Data Items

The following describes the variables that were selected, mapped, and digitized for suitability analysis.

a. State and Federally Owned Properties

A thorough inventory of both State and federal properties was initiated and their locations mapped. The inventory includes the size of the parcel, the agency holding title or utilizing the parcel, and the use of the parcel.

All available maps or lists containing State and federal property were accumulated by the Department of State Planning staff. These included tax maps at 1"=400' or 1"=600', computerized listings, and other similar kinds of materials. Each map and corresponding list was matched to determine their internal accuracy. Due to varying sources of data, discrepancies inevitably were identified, and substantial amounts of time and effort were expended in rectifying these discrepancies.

Lists were developed for properties which could not be located. These properties were listed by county and by probable agency ownership. Properties of less than 10 acres in size were omitted from these lists because of their lack of importance for Generalized Land Use Planning. Exempt from this rule were State Highway Administration's parcels which, because of their location (i.e., at intersections of major highways or at key access points), were included even though their size was less than 10 acres. The lists were then distributed through the State Planning Coordinating Committee for their aid in locating the properties.

All mapping by the Department of State Planning's staff was done at a 1:63,360 scale, using as a base the State Highway Administration's map series.

Every mapped item appears in a corresponding automated library file. There is a one-to-one correspondence between mapped and library items. Library items contain the full number series (including the two-digit county number). Property descriptions follow the acreage figures.

b. Sewer and Water Service Areas

Since the counties are not required to update their comprehensive plan annually (especially noting amendments that occur throught zoning and subdivision actions), the Water and Sewer Plans, updated annually by each county, serve as the best indicator of the counties' intentions for development of conservation in a state-wide compatible format. The water and sewer plans for each county have been combined. Mapping indicates the area presently served by water and sewer as well as the staging for future provision of these services.

Utilizing the preliminary draft of state "regulations for planning water supply and sewerage systems," a classification system was established to standardize the great variety of terms used to describe the stages of facility development found in the county sewer and water plans. Every effort was made to insure inter-county uniformity under this new classification system. The various stages were grouped together, and each county scheme was adapted to a uniform system. All stages may not appear in each county, but areas from separate counties containing the same stage number have the same characteristics. The following discussion outlines the Department of State Planning's classification system which is applicable to both sewer and water service areas.

1. "Existing Service Area" shall mean that area that is currently served. "Under Construction" shall mean a work or works of community water supply and community sewerage systems where actual work is progressing or where a notice to proceed with a contract for such work has been issued as of the effective date of the plan, its amendment or revision.

2. "Immediate Priority" shall mean a work or works of community water supply and community sewerage systems for which the beginning of construction is scheduled to start within two years following the date of adoption of the plan, its amendment or revision by the County. "Five or Six-Year Period" shall mean that period, depending upon the County's Capital Improvement Program, five or six years following the date of adoption of the plan, its amendment or revision by the County.

3. "Ten-Year Period" shall mean that period of the six or seven through ten years following the date of adoption of the plan, its amendment or revision by the County.

4. "Twenty'Year Period" shall mean that period of the eleven through twenty years following the adoption date of the plan, its amendment or revision by the County.

0. Beyond twenty year period; no classification; water supply and sewerage system not planned.

Each new polygon created on the map was encoded using a two-digit number series, corresponding to the sewer code and water code (each 1,2,3,4, or 0 respectively). A total of 25 two-digit combinations could appear on the composite map.

c. Transportation Facilities

Data was collected on multi-modal transportation systems, including highways, mass transit systems, railroads, navigation channels, ports and airports, natural gas pipelines, and overhead electric transmission line rights-of-way.

A great variety of maps from both State and non-state agencies was used as source material. The State Highway Administration "Twenty Year Needs Study" was utilized along with maps from the Federal Power Commission, U.S.G.S. Topographic Maps, and Naval and Aeronautical Charts.

A total of 16 separate characteristics were encoded. Each item received a two-digit code as follows:

01 Railroad
02 Gas or Pipeline
03 Transmission Lines

Depths of Channels

04 Spoil Disposal Site
05 27 feet
06 35 feet
07 42 feet

Intersection of Controlled Access Highway with another Controlled Access Highway

08 Existing
09 Proposed

Intersection of Controlled Access Highway with a Non-Controlled Access Highway

10 Existing
11 Proposed
12 Combination of 2 R/W
13 Combination of 3 R/W

14 Airports and Property
15 Rapid rail
16 Commuter rail

d. Historic Sites

The inventory of historic sites provided by Maryland Historic Trust was transferred to locational maps and incorporated into the data base.

Usually, site numbers assigned by County for encoding purposes were the same as those contained in the Historical Trust Indices. Only those sites given a number in the Historical Trust Index were mapped by the Department of State Planning staff. If a site had an assigned number, it was included even if its description was not complete. There are some exceptions to this rule, providing for delineation of historical districts and areas with large concentrations of historical sites.

An automated library system was created containing various bibliographic data for each corresponding historic site.

e. Existing Land Use

Existing land use is considered a suitability parameter because it is illustrative of present commitments of land and trends of land use.

The Department of State Planning prepared, in conjunction with the U. S. Geological Survey - Geographical Application Program, a land use inventory based primarily on high altitude color infrared aerial photography acquired by the National Aeronautics and Space Administration (NASA) in 1970 as Mission 144. This mission covered an extensive area of the State, including all but three Western Maryland counties. It was one of the first high altitude (60,000 feet) flights flown as part of the NASA-Earth Resources Technology Satellite (ERTS) Program, which included portions of five states. Added materials were obtained for Western Maryland, completing the state-wide inventory. This effort provided the State with a state-wide inventory of land use.

Unlike the other variables in the data bank, land use was mapped at a scale of 1"=2 miles. Seven regional maps were prepared and refined for digital encoding.

Recently, additional photography of the same type has been obtained for the entire State (1973). Based on this photography,

the land use maps have been revised. The base map scale for this effort was changed from 1"=2 miles to 1"=1 mile. The classification system for certain key categories was also increased in detail.

The land use classification systems used in both of these efforts are shown below:

<u>Original</u> - <u>1970</u>

11. Residential
12. Commercial and Services
13. Industrial
14. Extractive
15. Transportation, Communications, and Utilities
16. Institutional
17. Strip and Clustered Settlement
18. Mixed
19. Open and Other

21. Cropland and Pasture
22. Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas
23. Feeding Operations
24. Other Agriculture

31. Grass
32. Savannas (Palmetto Prairies)
33. Chaparral
34. Desert Shrub

41. Heavy Crown Cover (40% and over) Forest
42. Light Crown Cover (10% and over) Forest
43. Shrub Growth

51. Streams and Waterways
52. Lakes
53. Reservoirs
54. Bays and Estuaries
55. Other

61. Vegetated Wetlands
62. Non-vegetated Wetlands

71. Salt Flats
72. Beaches
73. Sand Other than Beaches
74. Bare Exposed Rock
75. Other

<u>Revised</u> - <u>1973</u>

110 - Residential
111A - Single unit residential, Low SUR Density
111B - Single unit residential, Medium SUR Density

111C - Single unit residential, High SUR Density
112A - Multi-unit Residential - Low MUR Density
112B - Multi-unit Residential - High MUR Density
113 - Mobile Home and Trailer Parks
120 - Retail and Wholesale Services
121 - Retail sales and services (commercial)
122 - Wholesale and services and light industries
130 - Industrial
131 - Heavy Industries - heat processing
132 - Heavy Industries - metal processing
133 - Heavy Industries - chemical processing
140 - Extraction
141 - Coal (surface mines)
142 - Other quarries and pits
150 - Transportation Communication and Utilities
151 - Airports and associated areas
152 - Railroads, including yards and terminals
153 - Freeways, highways, etc.
154 - Marine terminals
155 - Utilities
160 - Educational
161 - Elementary schools
162 - Secondary schools
163 - College and University
164 - Military Facilities
165 - Other Institutional
170 - Strip and clustered
190 - Open and other (Urban)
210 - Crop and Pasture Land
211 - Cropland
212 - Pasture lands
220 - Orchards
230 - Feeding Operations
410 - Deciduous Forest
411 - Upland Deciduous Forest
412 - Lowland Deciduous Forest
420 - Evergreen Forest
421 - Upland Evergreen Forest
422 - Lowland Evergreen Forest
430 - Mixed Forest
431 - Upland Mixed Forest
432 - Lowland Mixed Forest
440 - Upland brush
510 - Rivers
530 - Reservoirs
540 - Bays and Estuaries
600 - Wetlands
610 - Non-forested Vegetated Wetlands
620 - Non-vegetated Wetlands
720 - Beaches
740 - Bare exposed rock

3.1.1.3 Special Study Data Items

In addition to the 13 suitability and capability variables, several other data items were collected and digitized for special purposes. They are described below:

a. Watershed and Sub-watersheds

This variable consisted of a map description of all watersheds and sub-watersheds within the State. The variable will be used for mapping and analysis efforts using corresponding statistical data for each of these sub-watershed areas.

In addition, the variable can be used for extracting a variety of capability and suitability variables from the data bank by watershed planning unit. Specifically, the sub-watershed code allows the user to extract data listings, maps, or new data banks by specified watershed areas. This capability for data extraction reflects a response to the EPA Clean Water Act of 1972, requiring planning by river basin (e.g., the analysis of water quality, soils, vegetation, and land use, etc., by hydrologic units). Watershed and sub-watershed designations were mapped at a scale of 1:62,500 on county base maps. They were digitized using a 4 digit code.

b. Electoral Districts

Electoral districts are large zones used to summarize voting data within the State. There were two basic reasons for digitizing these maps. The first relates to interfacing census information. Census tracts and statistical area boundaries are nested uniformly within electoral districts. This enables data from the 1960 and 1970 census to be aggregated and used for computer mapping, various forms of analysis, and interface with the other data bank variables.

In addition to census data applications, tax and land use records were maintained at an electoral district level. Electoral districts were digitized from county maps at a scale of 1:62,500.

Each district was assigned the two-digit code in accordance with existing nomenclature. These codes must be cross tabulated with the county number for complete identification.

3.1.1.4 Summary of Data Items

The fifteen data variables described above came from over 30 sources and were compressed onto thirteen sets of maps covering the entire site. Mineral resources, aquifers, and aquifer recharge areas were placed on the same map series as were electoral districts and watershed/sub-watershed definitions. The codes for electoral districts and watershed were later separated as two distinct variables during the file creation process.

The base maps containing these 15 variables were remapped at three scales: 1:62,500; 1:63,360; and 1:126,720 (see Table 1). With the exception of land use, each variable was initially mapped and digitized on a county

basis. Land use was mapped and digitized as seven regions. The boundaries of these regions corresponded with county boundaries in all cases.

MAPPING SCALES OF DATA VARIABLES

TABLE 1

| Data Variable | Scale of Raw Data | Scale Used for Digitizing |
|---|---|---|
| Natural Soil Groups | 1:15,840 | 1:63,360 |
| Geology | 1:63,360 | 1:63,360 |
| Slope | 1:63,360 | 1:63,360 |
| Mineral Resources | previously unmapped | 1:63,360 |
| Aquifers | 1:250,000 | |
| Surface Water Quality | 1:62,500 | 1:62,500 |
| Natural Features | previously unmapped | 1:63,360 |
| Vegetation | 1:25,000 | 1:63,360 |
| Water & Sewer Service Areas | 1:24,000, 1:63,360 | 1:63,360 |
| Transportation Facilities | 1:63,360 | 1:63,360 |
| Public Properties | 1:63,360 | 1:63,360 |
| Historic Sites | 1:63,360 | 1:62,500 |
| Existing Land Use | 1:100,000 | 1:126,720 |
| Watershed | 1:62,500 | 1:62,500 |
| Electoral Districts | 1:62,500 | 1:62,500 |

In preparing the various maps for digitizing, it was most convenient to assign a numeric code to the map data before digitizing. Specifically, this involved converting the maps, codes, and various descriptions associated with the polygons, lines, and points on each map into a numerical code suitable for digital recording. This facilitated a rapid encoding procedure.

### 3.1.2 Referencing Map Data to State Plane Coordinate System

Most spatial data, particularly environmental data, is displayed on maps for common reference and analysis purposes. It is sometimes not realized that a map is seldom an exact replica of geography; it is, in fact, a "model display" which is used for communication, storage, and analysis. Frequently, because of the earth's curvature, maps do not represent the exact dimensions or proportions of the actual landscape. It is in this context that one may introduce the concept of map referencing or coordinate points as a significant and primary issue associated with storage of geographic data. Coordinate referencing can be associated with any number of spatial data orderings (e.g., tic marks on maps, x,y coordinates or landscape features, vector location of features, etc.).

It is important to note that geographic information systems differ from other information systems not only in the inclusion of locational identifiers, but also in the extensive use of these identifiers for manipulating data.

Examples of data manipulation are:

- merging maps from varying sources and scales into a unified data file (e.g., merging of county maps of differing scales to a uniform state-wide scale)

- selecting small geographic areas (windowing) from a larger geographic file (e.g., watershed planning units)

- "overlaying" map data files of two or more variables for the same geographic area (e.g., suitability/capability analysis)

- searching and calculating distances to or from a specific location or phenomenon (e.g., calculation of distance from a specific point to major transportation arteries)

All of these applications require consistent spatial identification. To obtain this consistency, a local version of the State Plane Coordinate System was adopted.

Plane systems assume that the earth's surface, or a portion of it, can be approximated with sufficient accuracy on a two-dimensional (planar) surface. The simplest plane systems are local in nature, and often have no relation to geodetically surveyed data, or even to other coordinate systems.

The State Plane Coordinate (SPC) System established for the United States comprises approximately 120 zones, each zone representing a separate planar surface.

This system utilizes the Lambert Conformal Conic projection or the Transverse Mercator projection in its representation, depending on the shape of individual states. Location of zones with relation to other zones is occasionally awkward but can usually be accomplished.

The S.P.C. System was chosen for Maryland because of the following:

a. the entire State falls within one of the S.P.C. zones

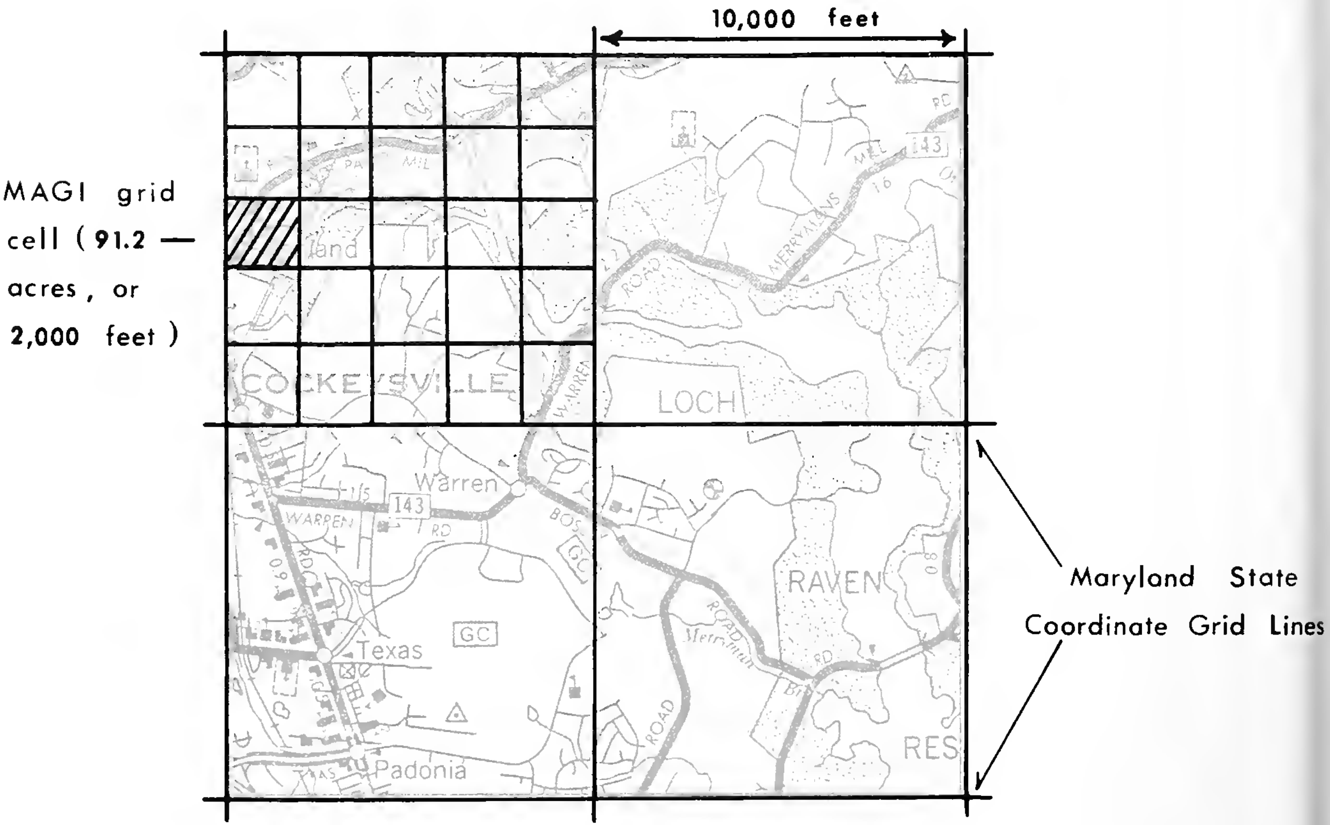
b. the majority of data historically collected with the State conforms to this mapping projection

c. the simplicity of the S.P.C. system makes it usable for graphic and other user output

d. absolute data accuracy for distances and areas (which requires a terrestrial system such as decimal latitude/longitude) was not warranted for the grid cell analysis of state-wide data.

Subsequent to selection of a coordinate system, each of the 13 data maps for each of the 23 counties and City of Baltimore and each of the regional land use maps for the State were referenced to the State Plane system. This required the delineation and numerical description of all x,y coordinate locations identifying the intersection of State Plane Coordinate lines. These points were then used as reference locations for all spatial identification measurements completed for each map.

Two systems for digital encoding were employed; they are referred to as manual encoding and automatic encoding. For manually encoded maps, a grid at a scale of 10,000 feet per line corresponding to State Plane Lines was drawn on the map to provide a generalized reference for a smaller grid overlay. The smaller grid was at a scale of 2,000 feet per encoding cell and was drawn on a clear acetate overlay. Preceding the digitizing process, the acetate grid overlay was matched with the State Plane Lines on the map (Figure 7). The rows and columns of the grid were then numbered sequentially, relative to an origin point at the upper left hand corner of the map. This origin point was always selected at the intersection of two State Coordinate Grid Lines. Later, when the county maps were merged to a State file, these points were used to locate the maps relative to the State Plane Coordinate System and to one another.




MAGI Grid System

MAGI Grid System
Figure 7

The base maps described in the previous section were delineated at three separate scales. Therefore, three separate grid cell sizes had to be produced. These scales and associated grid cells were:

| | Scale | Grid Cell Size |
|---|---|---|
| a. | 1:62,500 (U.S.G.S. 15 minute county map) | .3840245" |
| b. | 1:63,360 (1"=1 mile county map) | .378" |
| c. | 1:126,720 (1"=2 miles planning region map) | .18939" |

Using a computer plotter, acetate grid overlays were produced for each of these scales.

During the process of overlaying the acetate grid on the base maps, there were occasions when the grid did not conform exactly to the State Grid lines drawn on the base map. These situations resulted from inaccurate base maps, or maps that had shrunk or stretched from their original form. In order to address these problems, the grid was moved around on the map to seek a "best fit" relative to the rows and columns of encoded data. Grid alignment lines were drawn on the base maps for accurate realignment of the grid during editing procedures and for future reference to the original encoded data.

If all the maps could have been produced anew, using a single stable base map series at a single scale, the obvious procedure would have been to draw the grid on the base map and avoid the process of projecting an overlay on each map to be encoded.

Preparation of maps for automated encoding did not require the alignment of a grid overlay. This involved the delineation of three State Grid reference points from each map sheet, together with precise geographic x,y coordinates expressing the location of these points relative to the State Plane projection system. These points were digitized and were referenced to the remainder of the data on each map. The same measurement system was used to digitize the three reference points and the actual polygon data on the base map. A computer program was used to calculate the horizontal and vertical scale of the digitizer's measurements, as well as to conduct map rotation, error correction on the map, and conversion of digitized coordinates into State Plane foot and inch measurements.

## 3.2 Digital Encoding of Map Data

Subsequent to re-mapping and/or referencing variables, each map was digitized. As previously mentioned, there were two basic procedures for digitizing. They were: 1) a manual effort of identifying the attributes or priority of attributes in each grid cell; and 2) the automated effort of using an electronic digitizer to measure the outline coordinates of polygon map data and associate attributes to each of these polygons. These techniques are explained in this section of the report.

### 3.2.1 Manual Encoding Techniques

As explained above, the manual encoding of the Maryland data involved the overlay of an acetate grid on each county or land use region map and the recording of all numeric codes described on the base maps to an assigned row and column location within the matrix grid system.

The numeric code for each cell was written on a specially designed coding form and was subsequently keypunched and used to create the automated files.

Certain procedures were followed in recording the codes within the cells. These procedures were adopted by the coding staff to insure consistency in coding. The first of these procedures related to the type of maps being encoded (i.e., polygon, line, and point maps); the second according to whether primary, secondary, and tertiary characteristics are being encoded within each cell. The procedures used are discussed below.

a. Polygon Encoding

For data mapped as polygons, the recording for a given cell was determined by the polygon which occupied the most grid cell area (i.e., the dominant polygon was encoded). Exceptions to this procedure are discussed below (see Primary, Secondary, and Tertiary Encoding).

Encoding was performed along a horizontal row of grid cells with observations recorded sequentially for each column. Using this sequential encoding scheme, each cell was made addressable by a row and column coordinate measureable from the original map (county or region). These rows and columns were congruent with State Plane Coordinate System measurements.

b. Line Encoding

As a general rule, the data mapped as lines (e.g., roads or stream networks) were recorded by determining the most important quality occupying a given cell. The codes were arranged in a numerical scale from the most to least important; the most important value in a given cell was assigned to that cell. Therefore, if two roads of varying size fell within the same cell, the larger road code was assigned. Cells without data were coded accordingly.

As with polygon data, a sequential coding system was used.

c. Point Encoding

Map data expressed as points (i.e., critical areas, land ownership, and historic sites) were encoded by the row and column locations and the numeric site codes. This scheme proved to be more efficient than sequential encoding of the point data. It required a modified file-generating program to produce standard single variable county files.

Separate files were created for situations where two or more units or data items fell within the same cell.

d. Primary, Secondary, and Tertiary Encoding

When the accuracy and diversity of polygon data exceeded the grid cell encoding unit (approximately 90 acres), secondary polygons were recorded as separate observations. For soil type, a third (tertiary) observation was also recorded when three or more polygons occupied the cell. Using this encoding technique, the accuracy of important and detailed data was maintained. Secondary and tertiary data were encoded to separate files in the data bank to enable comparison analysis with the primary observation. This allowed a more accurate consideration of these separate variations in subsequent analysis procedures.

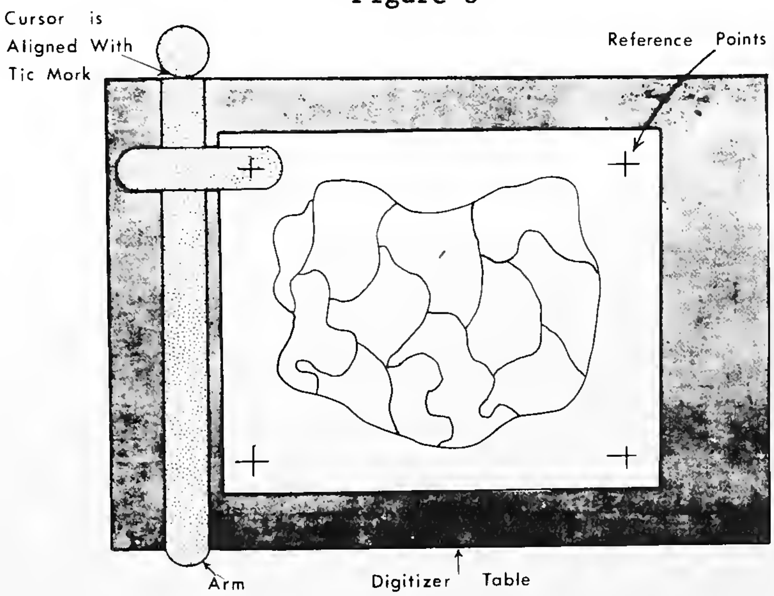
### 3.2.2 Automated Digitizing

The variables of watershed and electoral districts were encoded by using an automated technique. Both of these variables were polygon maps.

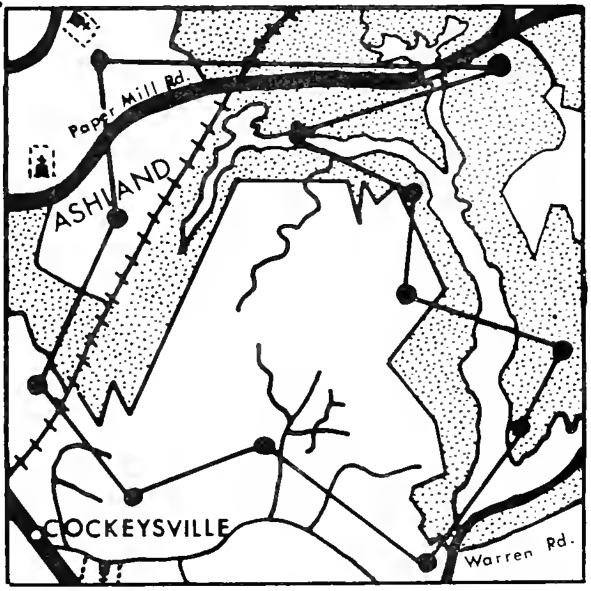
The conversion of polygon maps into digital input involved determination of the x and y coordinate locations of the lines which formed the polygon perimeters. The polygons were digitized using a method of point location encoding. To conduct this process, an electromechanical device known as a digitizer was used to convert horizontal and vertical movements of its cursor into computer compatible characters. The cursor was moved around each polygon, recording a series of x and y coordinates on paper tape. The data was subsequently transferred to magnetic tape for easier and more efficient processing. Figure 8 illustrates a typical map mounted on a digitizing table.

Diagram of the Method of Converting
Polygon Maps Into Digital Input

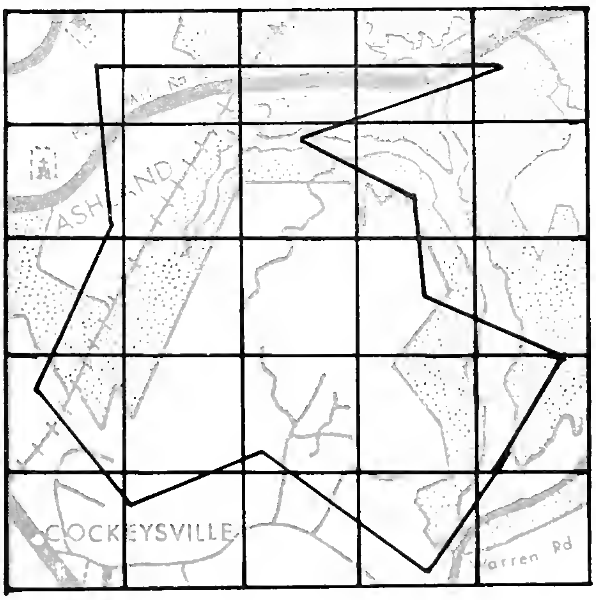
Figure 8



All measurements on the digitizer were made relative to the three State Plane tic marks which were used to reference the various county maps to each other. These three reference tics were used to convert all measurements to State Plane Coordinates. A special program (polygon to grid - "GRIPS") was used to convert this polygon data into a grid cell file compatible with the cell files that were manually encoded. This procell saved a considerable amount of detailed cell-by-cell coding and editing (see Figure 9).




Coordinate Outline
of Polygon




Grid Cell Attributes
Computed from Polygon

Calculation of Grid Cell from
Polygon (GRIPS)

Figure 9

### 3.3 File Creation and Editing Procedures

Referring to Figure 5, we can see that there were two separate procedures for creating and editing the Maryland geographic data files.

The manual encoding procedures required each data item to be encoded at the county level and subsequently mapped for editing purposes at that same level. Temporary data files created by these procedures were termed "single variable county files." After editing and updating these files, they were assembled into "multiple variable county files" for each county. These files were again edited and assembled into planning region files and finally into a multi-variable state-wide file.

Specific details and the significance of each of these steps is described below.

#### 3.3.1 Creation of Single Variable County Files

Thirteen map variables were encoded at a county scale, with a total of twenty-four files resulting from the primary, secondary, and tertiary encoding. Each of these files was treated as a separate data unit until all data was edited.

The Department of State Planning gathered existing maps, created new maps, and referenced all maps on a variable-by-variable basis for the entire State. This process took place over a 12-month time period. The digitizing effort overlapped this effort by approximately two months. Therefore, the digitizing and editing procedures had to respond to a single variable county map at a time. By mapping and editing each county as a single variable, the following benefits were obtained:

a. encoding and editing went on concurrently at various stages of map delivery;

b. encoding and keypunch staff were provided with timely feedback for problems in their work;

c. mapping and editing was done on small areas, thus reducing costly re-mapping of large files that had already been partially edited.

The first edit was performed by producing a computer map of each file and systematically reviewing it with the original base map. When the data contained too many sub-classifications to be mapped in meaningful levels for edit, a "scaling" technique was used with a card list of the keypunched data. For most data, maps were produced for a second graphic edit by the Department of State Planning. This was followed by a third set of maps which were "glance edited" to verify corrections.

Data encoded using an automated technique was plotted in order to verify the State Plane Conversion and the correctness of the digitizing. This was done using a drum plotter (Calcomp) which plotted the perimeter coordinates of each polygon as a line. A "double line" resulted where polygons intersected. Digitizing errors were identified by the divergence

of double lines which caused "silver errors." The polygons in error were redigitized and reinserted until a "clear" plot resulted. The polygon file was then converted into a grid file and mapped using the "GRIPS" program.

### 3.3.2 Creation of Multi-Variable County Files

After their final edit, the single variable county files were combined to form a multi-variable file for each county. In order to check for a direct overlay (i.e., edit for grid misalignment or study area irregularities), a special purpose mapping routine was programmed. By reading county files with this program, maps were output to indicate cells which contained data for some, but not all, variables. Edits then checked for three problem areas:

a. valid areas of mismatch where variables such as surficial hydrology were encoded past land mass portions of the county;

b. double drafting errors and subsequent encoding of the same information in two separate counties;

c. mismatches of data resulting from the grid alignment of maps at the two county scales.

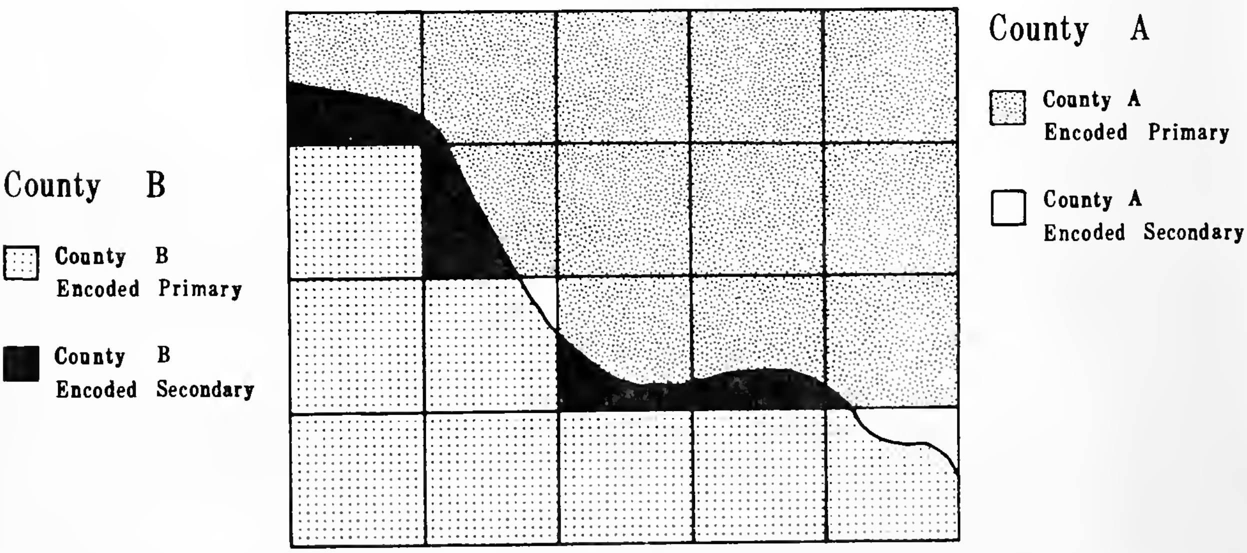
The errors occurring from problem areas a and b (above) were identified and corrected using the original base maps. There were no significant errors identified with problem area c.

### 3.3.3 Creation of A State-Wide File

While the creation of county files required a simple combination of the different data items collected for each county, the merging of counties required a somewhat more sophisticated technique. Decisions were required when adjoining counties contained data for the same cell. This situation frequently occurred even if a minority of the cell was contained in the county. An example of a common overlap situation is shown in Figure 10.

FIGURE 10

DIAGRAM OF A COMMON CELL OVERLAP PROBLEM



While overlap which requires decisions occurs even in ideal circumstances, it was anticipated that any problems in State Plane referencing of the drafted maps, or slight misalignment of the grid, would also create overlapping cells. Even though a slight error at the edges of the maps was acceptable, a systematic approach for correction was also warranted.

To perform this function consistently, the decision criteria were incorporated into the merging program (MAPMERGE). As an added step to insure accurate correction and recovery of data, the program printed conflicting data and the decisions made. This data was reviewed and edited on a cell-by-cell basis. The MAPMERGE program contained substantial logic for determining the data value that should be selected when overlap existed. Several examples of this logic for resolving overlapping data are shown below according to the "standard merge" decisions built into MAPMERGE.

| Old Master File (contains all files previously merged) | | | Update File (contains county to be merged) | New Master File |
|---|---|---|---|---|
| a. | primary soil | 813 | 521 | 813 |
| | secondary soil | 312 | 813 | 521 |
| | tertiary soil | 521 | 312 | 312 |
| b. | primary transportation | 10 | --- | 10 |
| | secondary transportation | 16 | 16 | 16 |
| c. | primary slope | 1 | 2 | 2 |
| | secondary slope | 2 | 3 | 1 |
| d. | primary soil | 221 | 111 | 221 |
| | secondary soil | 212 | --- | 111 |
| | tertiary soil | --- | --- | 212 |

The running of the MAPMERGE program for construction of the State file initially involved the assembly of the county files into regional areas corresponding to the land use regions. This step was required because the land use data was collected and digitized from planning region maps (1:126,720 scale). After the seven regional files were appended with the land use files, the state-wide file was assembled (using MAPMERGE). This was the final step in creation of the State master file.

The final state-wide data file contained twenty seven data items. They are listed on Table 2 in the order of their occurrence on the tape file.

TABLE 2

Data Items on the State-Wide File

| Variable # | Variable Name | # of Digits |
|---|---|---|
| 1 | Grid cell row number | 3 |
| 2 | Grid cell column number | 3 |
| 3 | county number | 2 |
| 4 | surface water quality | 2 |
| 5 | engineering geology (primary) | 2 |

| Variable # | Variable Name | # of Digits |
|---|---|---|
| 6 | engineering geology (secondary) | 2 |
| 7 | transportation facilities (primary) | 2 |
| 8 | transportation facilities (secondary) | 2 |
| 9 | ownership (primary) | 5 |
| 10 | ownership (secondary) | 5 |
| 11 | mineral resources | 2 |
| 12 | sewer and water districts | 2 |
| 13 | vegetation | 2 |
| 14 | soils (primary) | 3 |
| 15 | soils (secondary) | 3 |
| 16 | soils (tertiary) | 3 |
| 17 | natural features (primary) | 3 |
| 18 | natural features (secondary) | 3 |
| 19 | topographic slope (primary) | 1 |
| 20 | topographic slope (secondary) | 1 |
| 21 | watersheds and sub-watersheds | 4 |
| 22 | electoral districts | 2 |
| 23 | historic sites (first in cell) | 6 |
| 24 | historic sites (second in cell) | 6 |
| 25 | historic sites (third in cell) | 6 |
| 26 | land use (primary) | 2 |
| 27 | land use (secondary) | 2 |
| | | 79 |

## 3.4 Final Data Mapping of State-Wide Files

The MAGI system was developed with the capability of producing computer maps for editing as well as final display graphics. As previously described, the MAGI system is based on a grid matrix for digitizing, storage, and analysis of data. This same grid cell structure is also used for display of the data. This process involves the association of alphanumeric print symbols, or combinations of symbols, with the numeric code retained in the data bank. This type of map is produced with the aid of a computer line printer output device.

During the initial project, each of the basic variables in the data bank was mapped according to specifications supplied by the state planners. Many of these maps expressed a "collapsing" of the basic sub-classifications of variables into 10 or less mapped variations.

Because of the large number of sub-classes in certain variables (e.g., soils and land use), it was impossible to display all the variations on a single map. The two options available for handling this problem were: 1) making several maps, each displaying part of the sub-classification range (e.g., if there were 30 sub-classes, three maps could be made - each displaying 10 sub-classes); 2) collapsing the sub-classes into 10 or less mapped variations. In most cases, the second option was used.

An example of the collapsing procedure involved the mapping of the 30 soil series as 10 new classes related to capability for agricultural production. To accomplish this, the qualitatively defined natural soil series were grouped and associated with a quantitative ranking scale which indicated relative agricultural capability. This new quantitative scale was used for mapping.

| New Scale | Quantitative Soil Codes |
|---|---|
| Blank | all groupings with code numbers less than 130 |
| Level 1 | 211, 210 |
| Level 2 | 212, 213 |
| Level 3 | 221, 510, 530, 710, 531, 220 |
| Level 4 | 230 |
| Level 5 | 311, 312, 313, 320, 411, 412, 413 |
| Level 6 | 521, 522, 222, 223 |
| Level 7 | 610, 620, 630 |
| Level 8 | 720 |
| Level 9 | 720 |
| Level 10 | 811, 812, 813, 821, 822, 823 |

# 4. Generation of Interpretive Models

The modeling segment of the MAGI system is one of its most important capabilities because it involves the interpretation and use of the geographic data system for specific planning applications.

This section describes the generalized modeling process as well as several of the specific models that were developed for Maryland.

## 4.1 Introduction to Modeling Procedures

For purposes of this project, a "model" is defined as a set of mathematical scales and relationships existing among geographic data which articulate a geographic condition or set of conditions. Most of the models developed for this project were descriptions of the suitability and capability of geography to support various land uses. These models used, as input, the various combinations of the data bank variables described in the previous section.

The final output of these models was a series of grid cell maps defining the geographic capability or suitability of the State for specific kinds of land use activities. Each grid cell was mapped with a value which expressed weightings assigned to one or more environmental characteristics of that cell or surrounding cell(s). The weighting of the environmental characteristics was established by analyzing the constraints and amenities of each data variable relative to all other variables, and finally relative to a specific land use activity being examined.

The best way to conceptualize this process is to imagine a map of a model describing "where best" housing should be located. Within this model, flat slopes and good soils would be given a higher weighting than steep rocky slopes because they are easier to build upon, and their use for residential development would normally result in the destruction of the fewest environmental resources. By developing this very simple model as a computer program, one could very quickly map the locations where residential land use should best be located and where it should not be located.

The models can become extremely complex with many variables and decision points. In these situations, a matrix or flow chart is normally employed to illustrate the data relationships and weightings used as criteria for a model.

An example of how a matrix technique is used is shown below. If slopes are an important consideration for certain developments, the degree of constraint may be indicated by slope phase (zero being no constraint, five being maximum constraint).

| | | SLOPE PHASE | | | |
|---|---|---|---|---|---|
| | | (0-3) | (3-10) | (10-20) | (20 and above) |
| Land Use | Residential | 0 | 1 | 3 | 5 |
| | Industry (6) | 0 | 3 | 5 | 5 |

If depth to bedrock is being considered and weighted the matrix of model relationships may read as follows:

| | | DEPTH TO BEDROCK | | | |
|---|---|---|---|---|---|
| | | (0-18") | (18-36") | (3'-6') | (6'-12') |
| Land Use | Residence w/o basement | 2 | 1 | 0 | 0 |
| | Residence w/ basement | 5 | 4 | 4 | 0 |
| | Industry | 5 | 5 | 5 | 1 |

The weightings then can be integrated mathematically for any combination of slope phase, depth to bedrock, or land use activity by using a matrix.

A portion of the matrix may read:

| | | SLOPE PHASE/DEPTH TO BEDROCK | | |
|---|---|---|---|---|
| | | (0-3%/0-18") | (0-3%/18-36") | (0-3%/3'-6') |
| Land Use | Residence w/o basement | 2 | 1 | 0 |
| | Residence w/ basement | 5 | 4 | 4 |
| | Industry (6) | 5 | 5 | 5 |

The selection of the weighting factors can be both a subjective and objective process. When values are subjectively derived, they should reflect proposed policies, standards, and criteria which are generally acceptable. Changing the values or their relative rankings within a model can be considered a simple form creating alternative interpretations for plans based on alternative policy and standard criteria. Changing individual values may substantially alter the output, depending on the sensitivity of the weighting and the degree and type of interrelationships among the variables.

Objectively weighted models can also be developed. These modesl typically require more time and involve some form of scientific analysis and/or statistical analysis to generate appropriate values. An example of this type of analysis is regressing; whereby samples of existing or historic

phenomena are studied in terms of their mathematical correlation with specific variables (e.g., the probability of housing being located in a specific grid cell is some function of: land cost; accessibility; employment; environmental; legal, and engineering constraints; etc.). This modeling/weighting process can be thought of as an organizational structure for defining, testing, and expressing consistently the geographic processes, limitations, and amenities of natural and cultural landscape as mathematical relationships.

In developing a model of this type, there are three critical components:

a. definition of the specific objective of the model;
b. specification of the data variables that are critically related to the objective to be interpreted;
c. development of data relationships and weightings which express objectively some cultural or natural process or are responsive to a legitimate set of subjectively derived criteria or policies.

Because of the complexities of land use processes, it is not normally practical to construct a single model to describe a host of land use capability and suitability interpretations. The questions of land use are sufficiently complex to warrant the development of a series of independent models that can stand alone or be used in combination during the planning process.

In the development of a model, it is sometimes useful to segregate various geographic interpretations into sub-elements which together form the structure of the total model. For example, when developing a model of suitability and capability for low density residential development, one might hypothetically define the following considerations:

1. <u>capability considerations</u>

   a. environmental hazards
   b. engineering construction problems
   c. amenities of landscape

2. <u>suitability considerations</u>

   a. access (transportation)
   b. cost of land
   c. conflicting land uses
   d. social, economic and environmental impact resulting from the project

Each of these considerations has a series of data indicators which might be used in selecting or evaluating the constraints and amenities of a geographic location for this residential development. When developing the model criteria, it is useful to examine the indicators in the context of dynamic geographic processes which, when combined and weighted properly, provide the interpretation desired. For example, when evaluating environmental hazards, one might consider a series of landscape process models such as potential for flooding, mass movement, erosion, etc., as building block components of the total capability analysis.

One of the most important factors in developing a model is a thorough documentation of the decisions and weighting criteria used. This rule applies

to both objective as well as subjective interpretations. They must be well thought out and presented for discussion and interpretation. This is particularly critical when the final interpretation is to reflect public policy.

## 4.2 Specific Maryland Models

The selection of models for the initial application of the MAGI system was based on their application to the Generalized State Land Use Plan. The models related, primarily, to the "actions" of land use (i.e., the activities of man to be considered in the planning process, specifically relating to geographical location). The models were designed to reflect those land use actions most directly related to public involvement (e.g., public recreation areas) and those internal considerations which reflect public policy (e.g., conservation of agriculture, environmental impact, etc.).

Since the final product in this case was the State Land Use Plan, there was considerable justification for developing models having direct relationship to the categories of activities that may be addressed in the Plan.

The following models were developed to formulate the core of the planning process. A short description accompanies each model, indicating the nature of the output. It should be remembered that these models identify and rank the suitability for only those cells meeting the criteria of the models.

a. Mining/Extraction Model - identifies, by grid cell, areas suitable for the extraction of mineral resources (e.g,, stone, clay, sand/gravel, coal, natural gas, etc.).

b. Productive Agriculture Model - identified, by grid cell, areas best suited for intensive cropping or special practices (e.g,, orchards, tobacco, dairy pasture, etc.).

c. Urban Models - identify, by grid cell, suitability for each of the following urban land use sets:

  Urban Centers Model - areas where all functions of urban centers are included (e.g., high density residential, commercial, services, industry).

  Intensive Residential Model - areas including and relating to residential centers (e.g., schools, commercial/services, light industry).

  Low Intensity Residential Model - large lot or clustered development with surrounding open space containing the fabric of a community including schools, neighborhood commercial establishments, etc.

  Industrial Location Model - heavy industry and large scale commercial activities. Sub-model(s) may be constructed to specifically handle ports and marine facilities, power plants, and petro chemical facilities.

d. Conservation Model - identifies, by grid cell, areas which should be designated permanent open space, wildlife habitat, watershed, and airshed protection.

e. Forestry Model - identifies, by grid cell, areas suitable for maintaining the State's forest product industry and other forest activities.

f. Fishery Model - identifies, by grid cell, areas that must be managed to insure the continued viability of Maryland's fisheries industry.

In addition to the six basic models, additional sub-models were developed as supplements. They included the following:

a. public recreation areas
b. accessibility (re: transportation system)
c. natural processes and hazards
d. agriculture encroachment models
e. tourism model (recreation sub-model)
f. wildlife habitats

For discussion purposes the agriculture model is outlined in detail within this report.

### 4.2.1 Agriculture Model

The agriculture model was selected for presentation because it illustrates a simple technique for the comparison and interpretation of several geographic variables. The model identifies a value within each grid cell by searching for various combinations of land use type and soil series. This value is defined along an ordinal scale (i.e., one combination of soil and land use is better or worse than another combination). The model does not attempt to describe how much more suitable one combination is than another. The map created using the model ranks all grid cells in 10 levels according to their capability and suitability for agriculture. Soil series is used to describe "capability," and existing land use is used to describe "suitability."

Therefore, a cell containing predominantly good agricultural soils as well as existing agricultural land use is both capable and suitable for agricultural activities. It would, therefore, receive a high value (i.e., 10) on the map. Conversely, if a cell has predominantly poor agricultural soils and contains urbanization, it would have both a low capability and suitability rank (i.e., level 1 or 0). The criteria used for evaluating soil series according to their agricultural capability was derived from Soil Conservation Service ratings.

The categories displayed on the final map are listed in the following order of importance:

Blank = unsuitable and uncapable cells
1 = agricultural or orchard land use covering poor agricultural soil
2 = forest land use covering poor agricultural soil
3 = urban land use covering truck farming soils
4 = urban land use covering prime soils
5 = forest land use covering truck farming soils

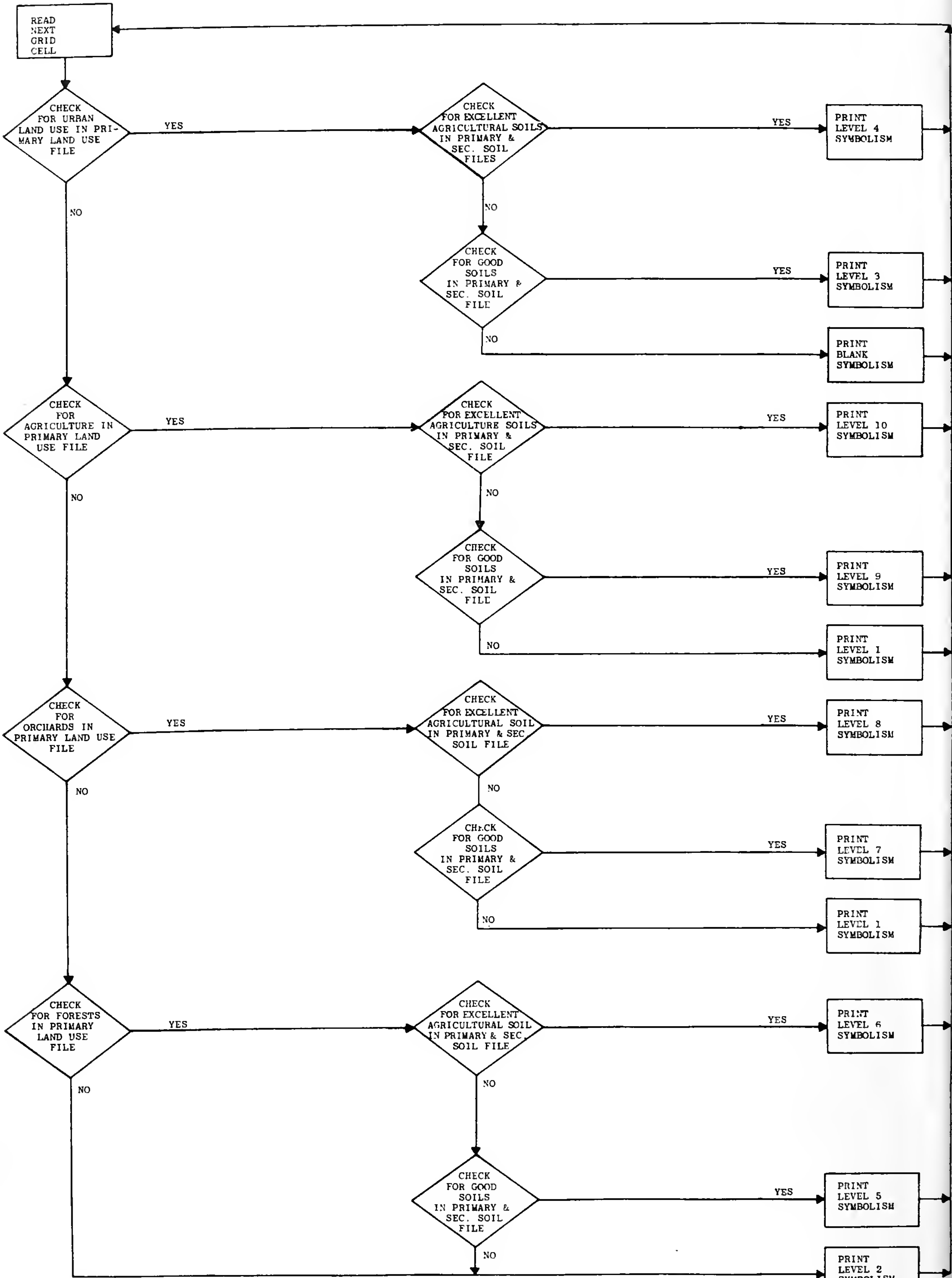

READ NEXT GRID CELL
CHECK FOR URBAN LAND USE IN PRIMARY LAND USE FILE
YES
NO
CHECK FOR EXCELLENT AGRICULTURAL SOILS IN PRIMARY & SEC. SOIL FILES
PRINT LEVEL 4 SYMBOLISM
CHECK FOR GOOD SOILS IN PRIMARY & SEC. SOIL FILE
PRINT LEVEL 3 SYMBOLISM
PRINT BLANK SYMBOLISM
CHECK FOR AGRICULTURE IN PRIMARY LAND USE FILE
CHECK FOR EXCELLENT AGRICULTURE SOILS IN PRIMARY & SEC. SOIL FILE
PRINT LEVEL 10 SYMBOLISM
PRINT LEVEL 9 SYMBOLISM
PRINT LEVEL 1 SYMBOLISM
CHECK FOR ORCHARDS IN PRIMARY LAND USE FILE
CHECK FOR EXCELLENT AGRICULTURAL SOIL IN PRIMARY & SEC SOIL FILE
PRINT LEVEL 8 SYMBOLISM
PRINT LEVEL 7 SYMBOLISM
PRINT LEVEL 1 SYMBOLISM
CHECK FOR FORESTS IN PRIMARY LAND USE FILE
PRINT LEVEL 6 SYMBOLISM
PRINT LEVEL 5 SYMBOLISM
PRINT LEVEL 2 SYMBOLISM

Figure 11

6 = forest land use covering prime soils
7 = orchard land use covering truck farming soils
8 = orchard land use covering prime soils
9 = agricultural land use covering truck farming soils
10 = agricultural land use covering prime soils

In processing these categories, a decision flow chart for selecting various combinations of soil and land use was used (see Figure 11). The chart illustrates the basic logic employed in selecting pairs of land use and soil series, as well as assigning them specific rank order for display on the map. A narration of this logic is provided below:

a. the program reads in the land use and soils attributes for the first cells in the data bank

b. the program checks to see if the primary land use in the cell is urban

c. if the primary land use is urban, the soils are checked

d. if soils are prime agriculture soils, the cell is mapped as level 4, and the next cell is read in

e. if the soils are truck farming soils, the cell is mapped as level 3, and the next cell is read in

f. if the soils are poor, the cell is printed with blank symbolism, and the next cell is read in

g. if a cell is not predominantly urban land use, the program checks for agricultural land use

h. if the land use is predominantly agriculture, the program checks soil

i. if soils are prime agricultural soils, the cell is mapped as level 10, and the next cell is read in

j. if the soils are truck farming soils, the cell is mapped as level 9, and the next cell is read in

k. if the soils are poor , the cell is mapped as level 1, and the next cell is read in

l. if agricultural land use does not exist in a cell, the program checks for orchard land use

m. if primary land use in the cell is orchards, the program checks soils

n. if soils are prime agricultural soils, the cell is mapped as level 8, and the next cell is read in

Decision Flow Chart Used in Developing the Agriculture Model

Figure 11

o. if soils are truck farming soils, the cell is mapped as level 7

p. if soils are poor, the cell is mapped as level 1

q. if no orchard land use exists, the program checks forest land use

r. if soils are prime agriculture soils, the cell is mapped as level 6, and the next cell is read in

s. if soils are truck farming soils, the cell is mapped as level 5, and the next cell is read in

t. if the cell contains poor soils, it is mapped as level 2, and the next cell is read in

u. if there is no primary orchard land use in the cell, the cell is mapped as blank and the next cell is read in.

# 5. Review and Final Analysis

## 5.1 A Critical Analysis of the System

The following is a general discussion of the problems and experiences associated with the project. Possible solutions to problems are presented in the hope that they will minimize difficulties on future projects of a similar nature.

The first problem surfaced during identification of the existing data sources available within the State. In many cases, an overprotective bureaucratic system hampered efficient information flows, making it difficult for researchers to acquire data from various agencies. This data included published or unpublished reports produced by federal, State and sub-state agencies, raw data sets, a variety of map information, and relatively scarce published material from the private sector.

Raw data and unpublished reports were the most difficult to obtain. This difficulty was caused generally by an apprehensiveness about its possible misuse or misinterpretation by the people maintaining the data. In an effort to overcome this concern, agreements were made with the data source agencies to produce a set of technical manuals describing each data variable in terms of its source(s), the method by which it was created, the process used to reformat it for planning interpretations, and the limitations imposed by the nature of the original data.

In situations where it was difficult to get full cooperation from the data source agencies, a complete presentation of the data system was necessary. Normally this included presenting the ways in which the complete data system could help the source agency in satisfying its own data and analysis needs.

Selecting a data source when several sources were available was a second problem. Initial selection of variables was based first, upon their usefulness in making planning decisions and, secondly, on the level of technical problems involved in reformatting them for computer encoding. In many instances (particularly the suitability variables), the "recentness" of data was a dominant factor in determining its usefulness: existing land use data was a case in point. 1960 data was available at a convenient scale for digital encoding but was insufficient because of the great growth in Maryland in the past 14 years. 1970 data was much better, but the scale and geographic projection of this data created substantial problems for digital encoding. 1970 data was encoded, but the final data records were less than perfect for all situations. After encountering these problems, it was realized that the 1973 land use inventory would far exceed the value of previous data in terms of classification significance, scale, accuracy, and timeliness.

Soils, geology, and slope data, however, were examples of data having long-term utility. In two counties the 1923 soils survey was used as the foundation of natural soils grouping maps with little less in the reliability of the data.

The interpretation of data collected in raw form was a third problem. This interpretation (particularly of physical geology) met with some hesitancy by professionals in the specific field. These personnel had difficulty with extrapolating raw data and its associated interpretations to areas surrounding sample points (e.g., hard rock borings). This problem did not occur with soils interpretations, primarily because of the long history and tradition of soil scientists interpreting various soil types (from field surveys) for specific agricultural pursuits. Soil scientists have a more consistent method for surveying and interpreting and also have a more predictable data type.

Reformatting data to a "common base" for both encoding and interpretive work created the greatest problem. A tremendous amount of manpower was necessary to reformat the data. Although each variable had a unique combination of reformatting problems, the problems themselves fall into five categories:

a. original map scale
b. original map projection
c. original map material
d. mapability of raw data
e. typing data to a common coordinate system.

The scales of original source maps varied widely and included 1:15,840 (soils), 1:20-25,000 (vegetation), 1:62,500 (geology), 1:63,360 (highways), and 1:100,000 (land use). (See Table 1, Section 3.1.1.4.)

A group of cartographers remapped these raw data maps to either the 1:62,500 or 1:63,360 scale. The only exception was 1970 land use data which was remapped at a 1:126,720 scale to insure mapping accuracy.

The 1970 land use maps created a problem because of their map projection. The maps were originally prepared by U.S.G.S. according to the Universal Transverse Mercator (UTM) projection while all the other maps were based on the Lambert Conformal Conic Projection. The land use maps required a transformation of projection during the digital encoding procedure.

The original raw data maps, being of various ages and conditions, had shrunken or stretched disproportionately, causing the mapping surfaces to be distorted. This made it impossible to overlay any two maps for the same area and retain registration. Many hours were spent in rectifying the displacements and/or distributing the distortions uniformly across the maps to minimize the amount of error.

At the beginning of the project it was felt that in certain situations it might reduce cost for digital encoding if two variables were placed on the same map instead of digitizing them independently. In some cases, this procedure proved effective in reducing the costs (e.g., watersheds and electoral districts). In other cases, however, this procedure resulted in increased expenditures. By combining sewer service areas and water service areas, additional cost resulted from the considerable drafting work required before digital encoding. In this case, the two variables were mapped on independent map sheets at a common scale and projection. The two separate variables were subsequently overlayed and assigned unique numerical identifiers,

then remapped on a third series of stable base map sheets.* This triple mapping effort resulted in about the same amount of expenditures as would have occurred if the two variables were digitized independently.

The alignment of the grid overlay with the State Grid Lines on the mapped material created the most significant problems. In the encoding and editing process, it was extremely difficult to align the grid overlay in the same position each time the map was handled. Map material distortion (shrink/swell) had created instances wherein State Plane Lines did not conform to the original five grid cell x five grid cell matrix. This problem could have been avoided by superimposing the entire net of 91.2 acre cells on the variable map via a photographic process and working (encoding, editing) from this copy.

The last difficulty to be discussed is a potential one involving updating data. This is not a limitation of the information system, but rather a short-coming of the procedures for collecting and maintaining information on the State. In some cases (e.g., soils, geology) the basic data will not vary substantially from year to year. Modification of these relatively stable variables will present no major effort. Updating data which is dynamic in nature, specifically existing land use and publicly-owned lands, can be more difficult. Land use changes at differing rates in different locations within the State, making it difficult to monitor except by remote sensing updates. There is no single agency within the State monitoring, as an ongoing operation, this type of change. The responsibility for maintaining and updating the files must, therefore, be within the state planning agency since they are most in need of periodic renewal of the data base.

## 5.2 Limitations and Future Applications of the System

As discussed in the Introduction, the MAGI system was initially designed to fulfill the immediate information needs required for preparation of the Generalized State Land Use Plan. The data base and computer system for manipulating it will, however, have a considerably broader utility. This section describes some of the additional applications that will be realized in the future.

Basic to this discussion is the understanding that although the system was designed to meet a wide range of information requirements for the State, it will not fulfill all of the needs for planning and analysis.

Inherent within the system are a number of limitations which must be recognized prior to its application as a planning tool. The first of these deals with scale. The 91.2 acre grid cell was selected as an amenable cell size for generalized regional planning efforts. It cannot be used for retrieval or analysis of data which describes in fine detail the variation of geography. For example, when considering point information, one is able to know that a point (e.g., historic site or critical area) exists within the 91.2 acre cell and not the detailed location of that point. In the case

* It should be noted that any time data was reformatted, it was done so on a stable base (mylar) material to minimize future material distortion problems.

of polygon data wherein only the primary attribute was digitized, the data structure describes geography by making the assumption that the dominant characteristic is completely homogeneous within that particular cell. The technique of encoding primary, secondary, and tertiary attributes within a cell was an attempt to overcome this problem, and for generalized studies this procedure is quite acceptable. However, when analyzing the environmental characteristics of small parcels of land, the system cannot provide fine scale map data necessary for many detailed investigations.

Another limitation is the classification system of the data itself. As previously discussed, several of the variables (e.g., soils and land use) are not subdivided into categories of lowest common denominator. Soils, for example, are categorized by soil series rather than distinct soil types. Although this aggregation by association is very well suited for generalized planning and analysis efforts, it cannot be substituted for the soil type data necessary for detailed investigations.

Data accuracy and age presents another limitation. Although many efforts were made to collect the most accurate and up-to-date data, there were situations where these objectives were sacrificed for consistent statewide information. This procedure is quite acceptable for generalized regional planning because interpolation and extrapolation, both in age and quality, are generally acceptable at a higher level of decision-making. As one decreases in scale, however, the problems of discontinuous anomalies of time and space become greater; therefore, additional data collection is required.

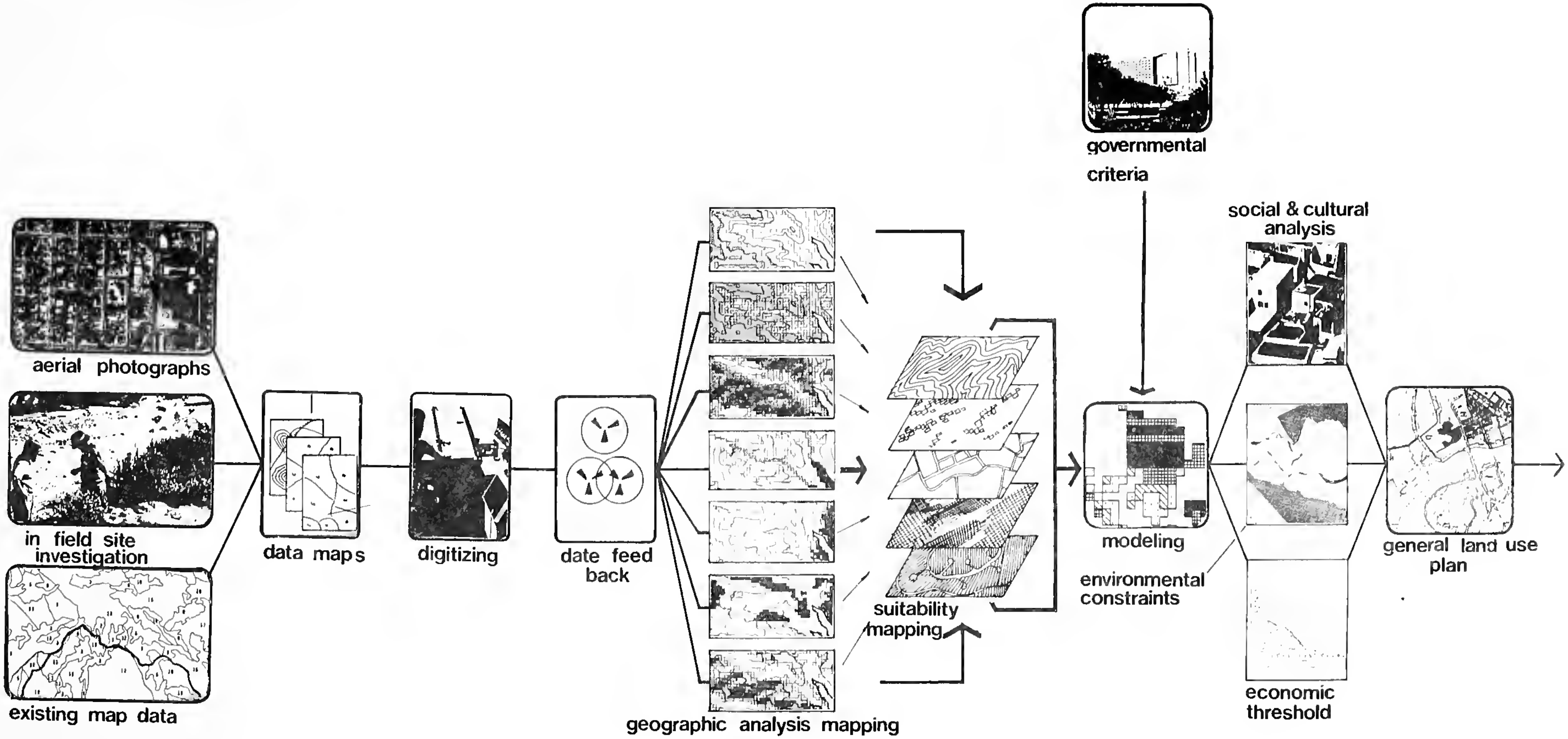
In summary, application of the MAGI system is limited to generalized planning and analysis investigations and, as such, cannot be rigorously applied to operational kinds of information requirements (e.g., detailed site planning, detailed tax assessments, building permit approval, address associated analysis, etc.). The system is, however, capable of interfacing and aggregating detailed automated data provided that it has coordinate spatial identification. This interface is accomplished by using various point in polygon, point in grid cell, and polygon to grid analysis procedures wherein spatially identified data is aggregated to the 2,000 foot grid using a computer software package. The DIME file system, developed by the Census Bureau for all S.M.S.A.'s in the country, is an example of a system that allows for aggregation of address and polygon associated coordinate data into grid cells.

The census, address, and other polygon associated data available from the DIME system is referenced to State Plane Coordinate street networks which can be aggregated to the Maryland grid cells using a Census Use Study software program entitled "GRIDS."

Realizing these inherent limitations, there still remain a host of effective and efficient applications for the system within the State of Maryland. The applications of the system fall into three categories:

a. planning and analysis studies (e.g., overlay analysis, gravity/search analysis, etc.);

b. project or plan review (e.g., environmental impact analysis);




INFORMATION PLANNING SYSTEM

Figure 12

c. basic data retrieval (i.e., maps, data listings, summaries,etc.);

The MAGI system will be usable by a number of State and local groups, as well as by private business and citizen groups. These users and their potential applications are summarized below.

a. Comprehensive State Planning Division, Department of State Planning

The Comprehensive State Planning Division, the sponsoring agency of the MAGI system, anticipates its use in a wide range of planning, coordination, and evaluation activities. The data base can provide meaningful input into the following efforts: a) review of wetland activity permits; b) review of county water and sewer plans and their impacts on land use; c) open space and recreation planning including the implementation and acquisition phase of the state recreation plan; d) other miscellaneous environmental analysis reviews; e) participation in the multi-modal transportation planning process; and f) preparation of the human resources plan (requires future expansion of the data base). (See Figure 12).

In addition to the above generalized applications of the MAGI system, it is anticipated that the data base will be extremely useful for special studies by the Department of State Planning. In the past, studies such as Assateague Island and the Analysis of the Proposed Annemessex Petrochemical complex would have been greatly assisted by the data base. Interest in special study applications has already been shown by several research groups. The first is a proposed NSF funded study on Preservation of Prime Agriculture Land; and the second is a joint State and federal government (Atomic Energy Commission) study for power plant siting.

b. Other Department of State Planning Divisions

The Department of State Planning, in addition to its mandate for preparing a State Development Plan, has the added responsibility for preparing the State's Annual Capital Budget, developing socio-economic data and projections, and housing the A-95 State Clearinghouse for federally funded projects. In each of these activities, the data base, particularly in future phases of expansion, will provide more and better data than is currently available. This will result in a better distribution of facilities, more efficient allocations of federal and State funds, less duplication of staff efforts, and more efficient staff utilization.

c. Other State Agencies

As knowledge of the MAGI system spreads through other State agencies, demands on the system, external to the Department of State Planning, will increase. Much of the data has applicability to the Department of Transportation, Health, General Services, and Natural Resources. In the latter case, the State's participation in the Federal Coastal Zone Management Act is an excellent example. The data embodied in the system can serve as a general data base, capable of integrating additional special purpose information related to this subject with the original data variables.

d. State Legislature

The State Legislature often seeks information from the Department of State Planning to support various legislative studies or committees. The ability to retrieve multi-dimensional data with short turnaround time will enable the Department to react in a more efficient and timely manner.

e. Local Governments (Counties and Towns)

Although several of the counties and towns in the State collect and maintain a sufficient level of planning and evaluation data, many of them do not. Therefore, it is felt that the MAGI system will provide a substantial data base for sub-state jurisdictions (i.e., counties and towns). Those counties or towns that do have sufficient data rarely maintain data on adjacent jurisdictions. Because of the continuous nature of the data collected, the MAGI system offers two additional opportunities: 1) to make data available to jurisdiction "A" concerning jurisdiction "B", where "A" might be effected or impacted by the events of "B"; and 2) to provide data about jurisdictions "A", "B", and "C" so that they can be compared.

f. Citizen Organizations and Unaffiliated Individuals

In recent years, citizens (both affiliated and non-affiliated with organizations) have sought and have gained increased participation in the governmental decision-making process. In its earlier stages this participation was generally restricted to "gut feeling" objections or support. More recently citizens have brought forth their positions with legal and technical support. In this advisory role the citizen groups and individuals have become both users and reviewers of government data. The MAGI system will permit the Department to interact with and support these groups in a more timely, complete, and efficent manner.

g. Private Industry

Private industry, particularly the development sector, having been affected more frequently by governmental actions (e.g., sewer moratoria, environmental impact reports, etc.) have become more sensitive to government considerations, particularly those relating to the environment. By making basic data available to the private sector and thereby working with a common data base, it is assumed that there will be fewer conflicts, with a substantial potential for increased communication and understanding.

The diffusion of data through these seven groups is most likely to occur in the order mentioned, though not in an exclusive manner. In theory, better data makes better decisions and the responsibility of the data holder is to disperse, not retain.

# TABLE 3

| | DATA IDENTIFICATION & ACQUISITION | ANALYSIS & REFORMATTING | ENCODING & EDITING | LIBRARY REFERENCING SYSTEM | PREPARATION OF MATERIALS | DATA MANAGEMENT | COMPUTER SOFTWARE DEVELOPMENT & DOCUMENTATION | MERGING & CORRECTION OF DATA FILES | FINAL IMPLEMENTATION & TESTING OF SYSTEM | COMPUTER MODELS |
|---|---|---|---|---|---|---|---|---|---|---|
| Soils | $2,600.00 | $11,300.00 | $13,835.00 | N/A | $6,000.00 | $5,700.00 | | $1,485.00 | | |
| Geology | 450.00 | 3,000.00 | 5,088.00 | N/A | 350.00 | 550.00 | | 990.00 | | |
| Slope | 500.00 | 2,150.00 | 3,727.00 | N/A | 350.00 | 650.00 | | 990.00 | | |
| Mineral Resources | 450.00 | 1,000.00 | 1,160.00 | N/A | 350.00 | 450.00 | | 220.00 | | |
| Aquifers | 400.00 | 1,500.00 | 1,000.00 | N/A | 350.00 | 400.00 | | 220.00 | | |
| Surface Waters | 200.00 | 1,100.00 | 1,150.00 | N/A | 300.00 | 300.00 | | 990.00 | | |
| Natural Features | 1,200.00 | 4,300.00 | 2,160.00 | $ 1,750.00 | 8,000.00 | 2,350.00 | $ 500.00 | 495.00 | | |
| Vegetation | 300.00 | 4,500.00 | 3,757.00 | N/A | 700.00 | 650.00 | | | | |
| Wildlife Habitat (Not Digitized) | 350.00 | 2,000.00 | | N/A | 700.00 | 650.00 | | | | |
| Sewer & Water Service | 500.00 | 1,600.00 | 1,010.00 | N/A | 1,000.00 | 600.00 | | 495.00 | | |
| Transportation | 200.00 | 2,800.00 | 1,420.00 | N/A | 700.00 | 300.00 | | 990.00 | | |
| Public Land | 500.00 | 2,300.00 | 1,031.00 | 1,200.00 | 1,000.00 | 200.00 | 500.00 | 990.00 | | |
| Historic Sites | 300.00 | 4,800.00 | 2,350.00 | 2,400.00 | 1,000.00 | 500.00 | 500.00 | 990.00 | | |
| Land Use (1970) | 500.00 | 1,000.00 | 2,568.00 | N/A | 500.00 | 650.00 | | 990.00 | | |
| Land Use (1973) | 200.00 | 30,650.00 | Planned | N/A | 500.00 | 200.00 | | 990.00 | | |
| Plans | 300.00 | 2,700.00 | Planned | N/A | 500.00 | 500.00 | | | | |
| Boundaries (Electoral Districts & Watersheds) | 300.00 | 2,250.00 | 3,750.00 | N/A | N/A | 500.00 | | | | |
| Non-variable Costs | | | | | | 2,250.00 | 6,440.00 | | 3,200.00 | 2,500.00 |
| | $ 9,250.00 | $78,950.00 | $44,006.00 | $ 5,350.00 | $22,300.00 | $17,400.00 | $7,940.00 | $10,835.00 | $3,200.00 | $2,500.00 |

# 6. Summaries of Statistics Relating to MAGI System Development and Operation

This section explains in detail the various statistics as related to costs of the project, computer usage, and overall management.

The cost (both in manpower and dollars) varied according to the type of task involved as well as the variable being worked on. This variation of costs by variable reflected not only the complexities of the data but also the many idiosyncrasies either in the initial data collected and mapped on display format or on scale, size, etc.

Table 3 summarizes the actual costs for each of nine categories of activity. These categories are further broken down in terms of specific variable.

The project involved digitizing over 70,000 grid cells for 24 variables, including primary, secondary, and tertiary. This data was taken from 391 maps. Many variables were not full coverage (i.e., including descriptions for every cell), and many of the variables coded as primary, secondary, and tertiary, or primary and secondary did not contain these values in each cell. The approximate number of observations recorded, however, was 800,000. This resulted in a coding, keypunch, edit, and merge cost of less than $0.07 per observed and recorded data item. The cost per grid cell for encoding all of the 24 variables, including spatial location, was approximately $0.78. These costs are approximately 39% of the documented costs for similar efforts done elsewhere.

Although the basic costs for development of the system are summarized in Table 3, the following information was generated to give the user a basic conception of the computation time involved in producing a single analysis or map. These breakdowns are the run times for a single run for each of the programs. They were made on an IBM 360-50, 256K.

COMPUTER PROCEDURES

| | | |
|---|---|---|
| 1. | merging county file to State file | 10-20 min. CPU *** |
| 2. | mapping single variable for total State | 10-13 min. CPU * |
| 3. | producing model/map for entire State | 12-14 min. CPU ** |
| 4. | creating window for one county (all variables) | 3-8 min. CPU *** |
| 5. | data listing for one cell | 1-5 min. CPU *** |

* depends upon number of levels on map
** depends upon complexity of model
*** depends upon geographic position within data bank